51st Congress, 1st Session. | SENATE. | Ex. Doc. No. 222.

LETTER

FROM THE

SECRETARY OF AGRICULTURE,

TRANSMITTING

A REPORT ON THE PRELIMINARY INVESTIGATION TO DETERMINE THE PROPER LOCATION OF ARTESIAN WELLS WITHIN THE AREA OF THE NINETY-SEVENTH MERIDIAN AND EAST OF THE FOOT-HILLS OF THE ROCKY MOUNTAINS.

August 21, 1890.—Referred to the Committee on Printing and ordered to be printed.

WASHINGTON:
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LETTER OF THE SECRETARY.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., August 20, 1890.

I have the honor to transmit herewith, in accordance with the act of April 4, 1890, a report on the preliminary investigation made to determine the proper location for artesian wells within the area west of the ninety-seventh meridian, and east of the foot-hills of the Rocky Mountains.

The report covers all the operations of this investigation, but I will have to postpone a full account of the expenditures to a later date, as there are still some outstanding accounts, etc., which must be adjusted before a final report of expenditures is made. I have thought it best, however, not to delay the transmittal to Congress of the report covering the scientific and statistical work of the investigation.

I may state briefly in regard to the expenditures, that making liberal allowance for outstanding accounts in course of settlement, it seems evident that the entire cost of the investigation, as ordered by the act, will not exceed $15,000.

I have the honor to remain, yours, respectfully,

J. M. RUSK,
Secretary.

The PRESIDENT OF THE SENATE.

REPORT

OF THE

SPECIAL AGENT IN CHARGE.

THE PROPER LOCATION OF ARTESIAN WELLS FOR IRRIGATION PURPOSES.

SIR: Under the provisions of an act entitled "An act to provide for certain most urgent deficiencies," approved April 4, 1890, an investigation was ordered to determine, as far as possible, the proper location of artesian wells for irrigation purposes. The appropriation thereunder became available the 14th of that month. The selection of a chief geologist and one of the field agents, as well as the general plan of operations, was determined upon at that date. On the 16th of the same month, by your appointment, I assumed control of the investigation called for as special agent in charge. I have the honor to report as follows:

It having been decided to organize the work on the basis of an engineering, geological and statistical inquiry, preparations were made for the selection of a suitable person or persons to conduct the same. Edwin S. Nettleton, supervising engineer for the Rocky Mountains, United States Irrigation Survey, under the Department of the Interior, was selected to take charge of the work of the engineering branch of the inquiry and to have supervision of the same in the field. Colonel Nettleton was detailed by the Secretary of the Interior on the 16th of April, and assumed the duties required by this investigation. Prof. Robert Hay, a resident of Kansas, had been selected as general field geologist, and communicated with by telegraph. Prof. G. E. Culver, of the University at Vermillion, South Dakota, was appointed field geologist for the States of North Dakota and South Dakota. Prof. G. E. Bailey, of the State School of Mines at Rapid City, South Dakota, who was formerly Territorial geologist of Wyoming, and as such had an extensive knowledge of the whole region in which he operated, was, on the 21st of April, appointed as assistant geologist, and given charge of the southwest portion of South Dakota and of eastern Wyoming. Prof. Lewis E. Hicks, of the State University and experimental agricultural station

of Nebraska, residing in Lincoln, was appointed field geologist for western Nebraska. Prof. E. T. Dumble, State geologist for Texas, was asked by the Department to take charge of the inquiry in that State. Prof. P. H. Van Diest, of Denver, Colo., a competent geologist and engineer, was at a later date selected as field geologist for Colorado. Prof. Van Diest has had a wider practical experience in the investigation connected with the geology of artesian basins and waters, than any other of the scientists associated with this inquiry. His fields of labor and investigation include Holland, the Netherland, East Indies, British India, Japan, California, and Colorado. The gentlemen named comprised the geological staff under the immediate direction of Professor Hay, who, in addition to his general field service, took charge of the geological investigation of western Kansas and the Indian Territory. The statistical work, which it was determined should aim at obtaining the history of all artesian wells within the region embraced by this inquiry, and incidentally also such other facts as were obtainable in the time at the disposal of the investigation relating to the waters found by bored wells, in springs or other sources of underground supply, was begun by the appointment of Mr. T. S. Underhill, railroad commissioner for the State of North Dakota, as field agent for that State, residing at Antelope. Mr. Stephen G. Updyke, professor of English literature at the State Agricultural College, Brookings, was appointed field agent for South Dakota. At a later date, Governor Mellette, of South Dakota, assigned to duty with this investigation the State engineer, Maj. F. F. B. Coffin, of Huron. This agent's service proved of considerable value, and of but little cost to the Department, his expenses in the work of the investigation having been allowed. Horace Beach, of Wisconsin, formerly employed by the Department of Agriculture as an expert in the well investigation and experiments made some years ago in Colorado, was also employed and assigned to duty in South Dakota with Major Coffin. His brief practical report will be found of interest. The central field division, consisting of Kansas, Nebraska, and Indian Territory west of 97°, with one degree of longitude in eastern Colorado, was assigned to Mr. J. W. Gregory, of Garden City, Kans., as field agent. The work of this division was heavy, and the duties of the agent have been intelligently and energetically performed, as his report will show. The remainder of Colorado east of the Foot-hills region, and all of eastern New Mexico, were embraced in one division and assigned to L. G. Carpenter, professor of irrigation engineering in the State College of Agriculture at Fort Collins, Colorado. Attention is called to the very intelligent report of Professor Carpenter, who deservedly ranks among the foremost of the younger scientists and engineers engaged in this great field of irrigation. Mr. Frank E. Roesler, of Dallas, Texas, was selected as field agent of that State west of the 97th meridian. His wide knowledge and indefatigable industry are shown in the mass of well-digested facts and intelligent statements that he presents. The field staff, comprising those thirteen gentlemen, was actively at work by the end of April, under the general instructions of the Department, as per letter of April 21 hereafter inserted. From that period until the close of their labors in the latter part of June, these agents were untiring in their industrious efforts to secure the data required under the law. The reports herewith presented from these gentlemen furnish an ample illustration of the spirit and energy they have displayed.

The immense area assigned to them, embracing as it does, over 658,000

square miles,* could, of course, within ten weeks be only partially covered. The selection of geologists and field agents was therefore made with a due regard to their possession of facts, and their previous knowledge of the conditions and wants of the sections to which they were assigned. Had it not been for their possession of such knowledge, and their wide and accurate acquaintance with the facts embodied, both scientific and economic, an intelligent report could not have been made within the time allowed. The activity of the field staff is shown by the statement that the chief engineer, Colonel Nettleton, and the general field geologist, Professor Hay, have traveled some 12,000 miles each. Mr. Gregory, in the central division, gives an itinerary of over 7,000 miles. The itineraries of other agents and geologists will make at least a total of 70,000 miles, all of which, besides a large amount of correspondence and other office work, was completed within ten weeks. This activity, it will be seen, was not attained at the expense of accurate inquiry. On the cessation of this field work, all became sedulously engaged in the preparation of the reports presented. The work of the special agent in charge, and of the experts under his immediate direction, besides caring for the general progress of the work, the forwarding of circulars of inquiry, the correspondence of the office, the examination and preparation of all accessible sources of information outside of the field investigation that bear upon the work in hand, included the preparation, printing, and forwarding of the following circulars which were signed by him, or by the various field agents sending out the same:

LETTER OF INSTRUCTIONS TO FIELD AGENTS.

U. S. DEPARTMENT OF AGRICULTURE,
ARTESIAN WELLS INVESTIGATION,
Washington, D. C., April 21, 1890.

DEAR SIR: Your acceptance of appointment as division field agent has been received. I desire to strongly impress upon you the necessity of great activity in the work with which you are charged. Congress has directed that a report must be made immediately after the ensuing 1st of July. In order to accomplish this, sixty days have been allotted to you. The blanks, forms, and circulars to be sent you will be your guide generally. This Department, however, expects you to record and forward, whenever it be possible without hindrance or cost to the investigation proper, all data and facts

**Areas covered by the artesian wells investigation.*

	Square miles.	Locality.
No. 1	147,700	North and South Dakota.
	27,462	Wyoming (east of 105°).
Total	175,162	
No. 2	65,845	Nebraska (west of 97°).
	54,075	Kansas (west of 97°).
	5,740	Public Land Strip.
	69,830	Indian Territory.
	19,250	1° of eastern Colorado.
Total	214,740	
No. 3	57,062	Colorado (east of 105°).
	48,303	New Mexico (east of 105°).
	163,500	Texas between 97° and 105° and as far south as latitude 28°.
Total	268,865	

Total area in square miles, 658,767.

obtainable, with your own observations thereon, as to underflow, subterranean, or other waters found within your division, which are now or can be made available for storage and irrigation purposes. These facts, when reported upon, must be stated without bias as to any particular system or plan of irrigation. The work before you relates directly to the question of artesian waters, well borings, etc., but all other facts relating to water supply, storage, and distribution within your division, may distinctly bear upon the subject of investigation and should, therefore, be forwarded to Richard J. Hinton, special agent in charge, at Washington, D. C.

You will report to him every three days, and oftener when necessary. The local answers to blanks, etc., received will be duly verified, consolidated by you, and forwarded to him. All personal field-work must be concluded by the 1st of June, at which date your full expense account must be rendered here. All reports from your division must be in the special agent's possession by the 10th of June. You will, therefore, see the necessity of taking the field-work in hand at the earliest possible moment, so as to secure the time required for consolidating returns and making reports.

E. S. Nettleton, supervising engineer of the United States Irrigation Survey, has been assigned to general charge of all the field-work. You will reply promptly to any communications and directions from him, forwarding copies of such orders and replies to this office.

Prof. Robert Hay is appointed a chief field geologist. Any communications from him should be met with prompt reply and information. The geologists or engineers investigating your division may also have occasion to communicate with you. Prompt attention to such communications will be necessary. In your regular report mention will be made of these matters.

The Department requires rigid economy in all expenditures. Reasonable allowance will be made for necessary travel, and you will, on receipt of this, make out a schedule covering such proposed travel, the reason why, and expense estimate therefor. Vouchers must be obtained for all hotel and other items.

It is fully expected that your best endeavors, knowledge, judgment, and activity will be given to this important work before you.

Very respectfully,

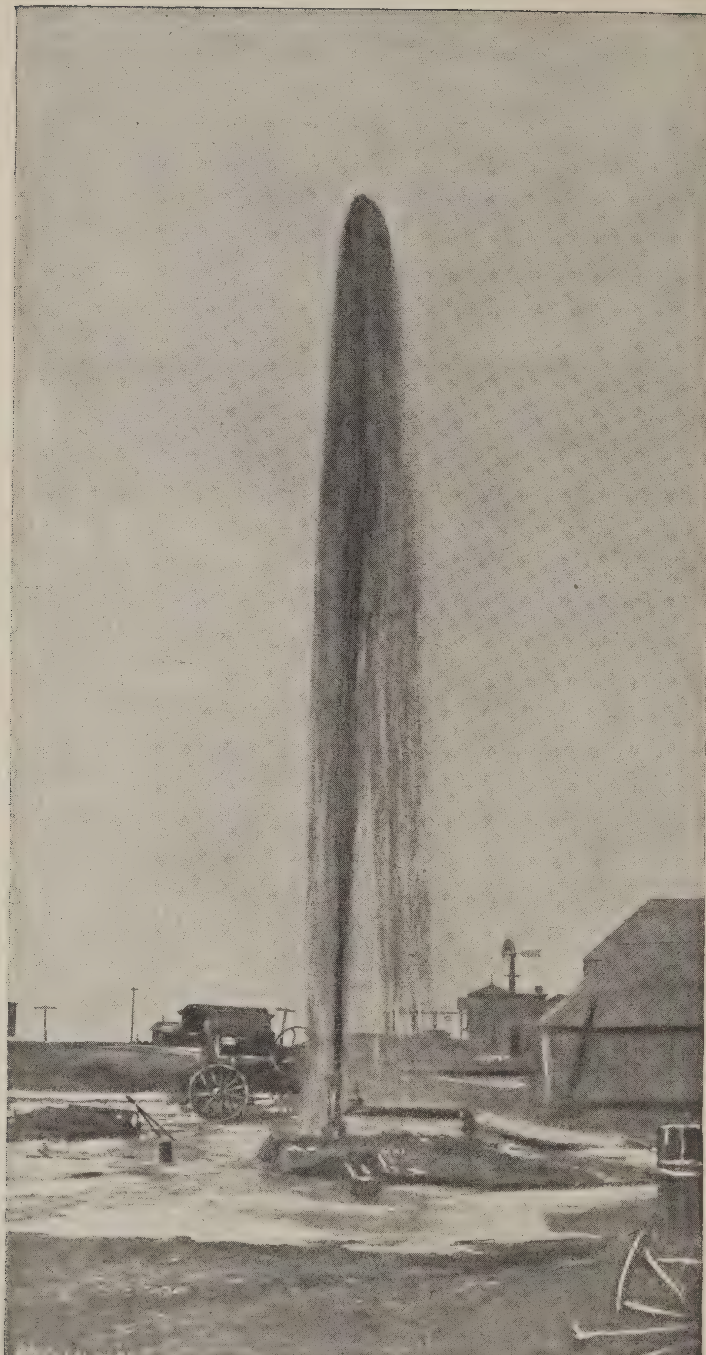
J. M. Rusk,
Secretary.

Copies of the circular of inquiry sent out by this office, and by the field agents under its direction, will be found attached to this report of the special agent in charge, marked Exhibit "A."

In addition to such circulars it was also decided to send out the following definition of artesian waters:

To include all subterranean waters which, on being reached or opened from above, are found to flow by pressure to a level higher than the point of contact. Another consideration is, that the said waters shall flow from some permanent and general source rather than from a local and temporary one. All bored wells in which the water rises, though not above the surface, may be included in the term artesian; also all natural waters, such as springs rising from below, are embraced in this definition.

The examination of the authorities justifies the foregoing definition. The artesian well may be considered as an artificial spring, or springs may be considered as natural artesian wells. Artesian waters have been divided into two kinds or classes, positive and negative. The positive artesian flow is where the water, when tapped, rises with force above the surface of the opening; the negative artesian water may be considered to embrace such supplies as, when tapped by boring, rise above their confined level, but not above or to the surface or source of supply. In the prosecution of their observations and the gathering of information, the statistical agents were especially directed to secure, whenever possible, without other cost to the Government than that of their labor, all information obtainable within their divisions relative to any other sources of supply favorable to and adapted to irrigation uses. Quite a mass of such information has been obtained, which will be laid before you. It will be submitted in a supplementary report under a resolution of the United States Senate.



ARTESIAN WELL AT WOONSOCKET, SOUTH DAKOTA, THROWING A FOUR-INCH STREAM 61 FEET IN THE AIR.

Depth, 725 feet; bore, 6 inches; discharge, 8,000 gallons per minute.

THE ARTESIAN BASIN OF THE DAKOTAS.

The field of hydrological engineering opened up by this investigation is one heretofore almost untouched by the scientific inquirer. The nature, character, and extent of under-ground water supply are subjects to which very little systematic attention has been given in the past, either here or elsewhere in the world. A rapid inquiry into such historic and economic details as are accessible presents an almost surprising mass of favorable facts. What has been learned is set forth in the accompanying reports. It may be well, however, to condense a few of the salient features.

The vast extent of the Dakota artesian basin is testified to by the inquiries and deductions of Messrs. Nettleton, Hay, Culver, and Bailey. Even a slight acquaintance with the chief features of the physical geography of the Dakotas would testify strongly to the probable permanency of the artesian water supply, which unquestionably is fed by the great drainage of the Rocky Mountains to the northwest. This drainage flow penetrates below the superincumbent stratum to the body of friable rock known as the Dakota sandstone, which appears to underlie the whole region. It is evident that the drill has nowhere more than penetrated a few inches of this water-bearing and conserving stratum. The altitude, the general trend of the land, and the formation and character of the great hydrological or river area which intersects it, give weight to the deductions that are made as to the extent and permanency of this remarkable artesian basin. There are found within it about 150 high-pressure artesian wells, including, with those in the Dakotas, the few bored in the Yellowstone Valley of Montana. There are also found in South Dakota several hundred flowing wells, whose supply is evidently from sources not identified with the greater artesian basin. In northeast Dakota, in the hydrological basin of the Red River, claimed by geologists to be the seat of an ancient lake, there can be found over a thousand small flowing wells, whose waters are used largely for farming and homestead purposes in garden and other small irrigations. No diminution of pressure is anywhere reported. The source of their supply is from the upper beds of glacial drift. There is reason to believe that a sinking of experimental wells may prove the possibility and probability of securing large artesian supplies westward of both the James and Missouri Rivers, and in a degree that will prove to be of great economic importance. The people who have settled in the Dakotas belonged, originally, to States wherein the practice of irrigation is unknown. Active settlement began in these two new commonwealths during years that were blessed with considerable rain-fall, and thereby the young communities were greatly encouraged and rapidly became prosperous. A few years, however, have proven conclusively that the element of insecurity as to rain-fall is really a permanent one. It would be folly to deduce from such a short period of years, as that in which observations have been taken, any theoretical dictum claiming authority for its statement; but it is evident, not simply from climatic observations in the Dakotas, but from those taken throughout the Great Plains region, and extending over a much longer period, that there is something like a periodicity of abundance and drought, covering, so far as can now be deduced from observation, cycles of from seven to nine years in duration. Another, and perhaps even a more important feature for the establishment of agricultural security in the Dakotas, as well as elsewhere on the Great Plains, is involved in the possibility of realizing a more equitable distribution of the rain-fall. It may reasonably

be assumed that over a large portion of the area under consideration the annual rain-fall is almost or quite sufficient, if it could be evenly distributed as to area or controlled in its fall as to time; but the fact remains that there is no equality in the distribution either as to area or time. It is not unwisely held by practical observers that the cultivation of the soil and the growth of plant life must enormously modify the primary and prevailing climatic features.

Evidence tends to show that human industry applied to the land has already greatly modified the phenomena of distribution. Naturally enough those who have observed such features have hastened to the conclusion that these modifications tend also to a permanent change of climate. It may, however, safely be assumed that only so much of this conclusion is correct as warrants a belief in the modifying and ameliorative effects, locally speaking, of human industry within our semi-arid regions. The Dakota farmers conclude, and wisely too, that their greatest need, at least for the present generation, is not to be found in attempts at the establishment of an extensive system of storage and distribution. What they desire and what they need are the exploitation and development of the supplies which lie beneath their feet, and which they may find immediately at their gates. Over the eastern half of these twin States they are not absolutely dependent upon irrigation, but for industrial security they need the power to draw upon supplies stored in wells or reservoirs during the ripening weeks that should bring harvest to them. The harsher and larger climatic conditions, at this period of need, prove too often destructive of all their labor and its results. Such a supply as will meet this want, not large, but imperative in character, seems to be at their command in the wonderful artesian basins that unquestionably lie within the borders of the two great States, and which will probably be found to also serve a considerable area of north and eastern Montana. More than a million persons reside within the northwest portions of the area embraced by this investigation. The unsurveyed public lands of the Dakotas will reach a total area of at least 27,000,000 acres. Nearly one-half of Montana, which must be favorably influenced by the development of this artesian supply, will contain about 32,000,000 of acres, making a total of not less than 59,000,000 acres of unsurveyed public land.

The people who had settled within this new northwestern section, and who have recently brought to the Union five great and important commonwealths, have paid into the Treasury of the United States, for the public lands they have reclaimed and made fertile, from $35,000,000 to $40,000,000. In the Dakotas alone the total of land payments exceeds $25,000,000. By adding the great sums paid by settlers to land-grant corporations we shall have, in all probability, a total of $35,000,000 for the Dakotas alone. A great net-work of railroads has already been constructed, and prosperous towns and villages have already been founded by the hundred. The Dakotas are famous in the markets of the world for the production of wheat. The commerce of the nation has been greatly increased by the growth and shipment of its particular and valuable grain. The people, widely scattered, heavily in debt for the means whereby they have begun the establishment of homes and industrial activity, are unable, therefore, to carry forward the important work of investigation and experiment upon the comprehensive scale that is required. They energetically ask that the General Government undertake the direction and cost of such experimental operations. The sinking at public expense of farm or community wells has not been demanded. It is stated upon the authority of leading citizens, not only in the Da-

kotas, but throughout the Great Plains, that with a comprehensive survey and a definite series of experiments, limited in number and cost, but assigned under proper directions to favorable sections, and to be undertaken by the General Government, that private capital and combined effort stand ready to carry forward to a successful issue the large amount of detailed inquiry, investment, and work that will be needed to establish a regional irrigation supply.

CONTROLLING GEOLOGICAL CONDITIONS.

Prof. G. E. Culver, the geologist for South Dakota, has made a report of singular interest; cautious, but still comprehensive. It shows that the great Dakota basin—a broad, low synclinal with a northeast trend—extends on the north from meridian 98° eastward, to nearly or quite 107° at Great Falls, Montana. It forms an irregular triangle, whose southern apex is at or about, the southeastern extremity of South Dakota, while the eastern line is an irregular one running generally from the meridian 98° to 98° 30′ of west longitude; it is therefore, at the upper or northern end, 9° of longitude, or about 550 miles wide. So far as its eastern rim has been located or suggested, it will have a length of about 700 miles. Directly from north to south, it will have nearly the same length as from east to west. The western rim is unquestionably near the foothills of the Rocky Mountains, following them down into Wyoming, and probably west of the Black Hills in that direction. The eastern rim is along the east line of the Dakotas. The valley of the James River, in which by far the greatest number of wells have been bored, is not to be considered, according to Professor Culver, as the central or pivotal portion of the basin. Geological investigation warrants the statement that the James River Valley is "simply a broad, shallow drift or depression in the eastern part of the artesian basin, and is in no sense a controlling factor in the problem as regards either the cause or the extent of the basin." Professor Culver, in a preliminary report made to the special agent in charge, states what the controlling factors are, and also what, in his judgment, is the origin of this remarkable basin. He says that they are:

(1) The position of the pervious Dakota sandstone between two impervious beds.

(2) The flexing of the whole series forming a low, broad synclinal.

(3) The tilting of the beds, giving a long easterly slope, with a slight rise near the eastern border of the basin.

(4) The exposure of the Dakota sandstone on the western rim, where mountain streams and drainage must cross it.

(5) The overlap of the Colorado shales and clays on the eastern border, sealing in the waters and allowing an accumulation.

The Red River Basin in the northeast portion of North Dakota obtains its water from rocks much older than the cretaceous. The high, deep pressure flow of this basin has not been developed. There are in this valley a great number of shallow wells of moderate flow and pressure, the water of which is found just beneath the glacial clays in recent beds of clay and gravel. A belt of wells somewhat similar to this has been found in the basin east of the James River in South Dakota. They are shallow in depth, and of character common to the wells of Nebraska and Kansas. The map of the Dakotas, accompanying this report, shows the location of these two minor basins. An important examination was also made of the geology of South Dakota lying west of the Missouri River, and of that portion of Wyoming lying west

of the Platte River and east of the foot-hills of the Rocky Mountains by Prof. G. E. Bailey. It is claimed in his report that the chief conditions requisite to artesian wells exist throughout the southwestern portions of South Dakota. These conditions are, as stated by Mr. Bailey:

(1) A porus stratum or water bearer, furnished by the Dakota sandstone.

(2) Impervious beds above and below the Dakota sandstone.

(3) A high fountain head in the Black Hills and mountain ranges along the western edge of the State.

In order to obtain an artesian basin, geologically speaking, the following conditions are necessary, all of which are found in the Dakotas:

(1) A pervious stratum to permit the entrance and passage of the water.

(2) A water-tight bed below to prevent the passage of the water downward.

(3) A like impervious bed above to prevent the escape upwards.

The first is furnished by the Dakota sandstone, a bed of from 250 to 400 feet in thickness; the second by the Jura-Triassic system of rocks, which are immediately below the Dakota sandstone and directly above the carboniferous limestones. The rocks above furnish what is known to geologists as the Colorado group. Other conditions needed to complete a basin are all found in the trend or inclination of the strata, a proper exposure of the porous stratum for collecting the water, and an adequate rain-fall, with absence of escape from local cause. These physical features are all found in the Black Hills region and, as Professor Bailey declares, are accompanied "with a gentle inclination of the strata to the east, thus making the entire area from the foothills of the Black Hills region to the Missouri River an artesian basin."

STRATAGRAPHY OF WYOMING AND NEBRASKA.

In the portion of Wyoming, Professor Bailey obtained the records of sixty wells, scattered for 45 miles wide on the belt extending from the northeast corner of the State to the center of Natrona County. These wells are all flowing, either salt or mineralized waters, or water impregnated with mineral oil. Gas was found in nearly every well, and in some cases enormous pressure was shown. From the geological examination the professor assumes that in the eastern portion of Wyoming a number of small artesian basins may be found, wherein good water could be obtained from the Dakota sandstone; that stratum seems to bear the same character that it does in the Dakotas. In the southeast portion of Wyoming, adjacent to the Nebraska line, another supply of subterranean water is available. The tertiary rocks and sandstones which are found are open and porous, and below them is a good water-tight stratum, while above the stratum is impervious. These tertiary rocks are generous water-bearers, and though the pressure of their supply would be very low, yet the water they contain can be easily reached, and by mechanical power brought with economy to the surface. The geologists regard "the development of the water in the tertiary strata as of the utmost importance," and urge a more thorough investigation. There are three sources of supply from which water is obtainable in Wyoming—on the east bank of the Big Horn and on both sides of the Powder River. It can be found also over a great portion of the table-land of the northeastern section. The Laramie rocks are good conservers of water, and a liberal supply may be ob-

ERRATA.

"porous" instead of "porus" on page 12, paragraph (1).
"STRATIGRAPHY" in place of "STRATAGRAPHY" in subheading, page 12.

tained from them with good pressure. The question of depth is a local one, varying with almost each township. Professor Bailey urges the importance and need of a larger investigation of that region, and presents his reasons therefor in a report which accompanies this.

Geologist Lewis E. Hicks, of Nebraska, offers an intelligent presentation of the stratigraphical conditions which determine in his field the direction, the flow, and the pressure of subterranean waters. Nearly all such waters in Nebraska "have a tendency to rise in wells and foreholes, and sometimes throw out at the surface." They come, therefore, within the definition of artesian water made by this office. Professor Hicks considers the rain-fall the ample source of this supply. The aggregate volume of such precipitation is enormous. It amounts, he says, "to more than 100,000 cubic feet on each acre, or 5,000,000,000,000 of cubic feet annually for the whole State." The mean discharge of all the rivers of Nebraska is estimated at nearly one-fourth of this great total. Evaporation and seepage absorb the balance. However, the "underflow along the incline bodies of porous rocks is undoubtedly a more important source of moisture than all the rivers which enter the State."

The existence of great levels of this sheet water has been determined and demonstrated. Many streams have a steadier volume in their channels than the precipitation and their incline warrant. It is believed that they are eroded deep enough to receive a supply of this undersheet flow. The water-bearing strata of the State are geologically known as the Perma-Carboniferous. The youngest rocks of the stratum are the most valuable. Artesian flow has been obtained from this stratum, and, contrary to usual experience, the limestones appear to yield more than the sandstones of the same area. The sand and sandstones of cretaceous origin, which lie upon the carboniferous formation, are also found to be good water conservers and yielders. About sixty-five wells are reported in Nebraska, and the conditions appear to merit the geologist's claim for further investigation and experiment. A very much larger area can be restored to cultivation by the use of wells from which the water is drawn by means of machinery. A notable fact in regard to the Nebraska undersheet water is, that in the western part of the State it moves under considerable pressure, and when opened rises rapidly to or very near the surface. Springs form an important part of the subterranean supply in the central part of the State, and also in the eastern portions, while the wide, shallow river beds are extensive basins of seepage water.

THE CENTRAL SECTION OF THE GREAT PLAINS.

Field Agent Gregory, in closing his careful report, reviews the conditions of the Great Plains region from the northern boundary of Nebraska to the southern boundary of the Indian Territory. He found within his division about two hundred flowing wells, with several hundred more in which the water rises but does not reach the surface. Accompanying his report are the records of numerous springs unquestionably artesian in character; but the great source of water supply in the central region must be looked for in the undersheet water found in the gravelly strata below the alluvial surface, and in greater quantities within the valleys of North and South Platte and of the Arkansas rivers.

Irrigation in the Central Division is to be supplied by carefully husbanding in local reservoirs and basins the unequal rain-fall of the region, and by application of mechanical power in drawing to the surface

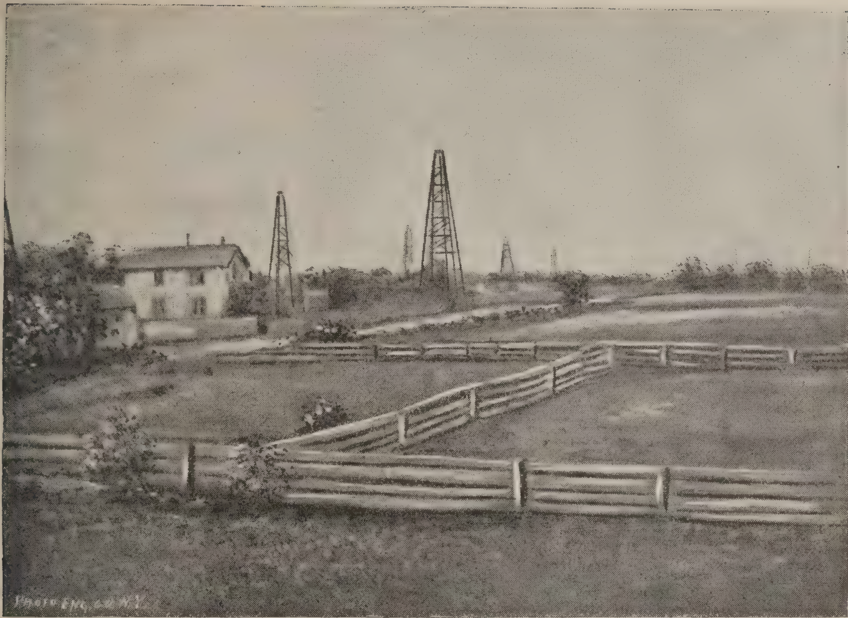
and distributing the undersheet waters. As in Dakota, or probably in an even more remarkable degree, the increase of cultivation and planting of trees for windrows, orchards, etc., wide opening of the earth, and the capillary powers of the plant roots in drawing water from below, are having a steady and increasing effect in the way of utilization of rain-fall and its distribution. The Kansas State rain-charts illustrate what is to be done in this direction, showing, as they do, how minor features of physical configuration reduce air currents and bring to or turn aside from given areas the fructifying moisture which is needed.

In Colorado there are four distinct artesian basins reported. That of Denver is at present the most thoroughly develeped. Water is found at from 65 to 1,000 feet deep. The flows are from 100 to 300 gallons per minute in each well, and it is used mostly for domestic purposes. A decided success has recently been made in serving market gardens of from 8 to 15 acres each. There are about 350 in this basin, of which at least 250 are still flowing. The decrease of flow is due to want of control by the municipal or other authority in the matter of boring, and also from the want of regulation, such as necessity has imposed in San Bernardino, Cal., by which advantage is taken of the periodicity of the supply. The Greeley basin is one of deep wells. The average depth is from 1,100 to 1,300 feet. The water is used exclusively for domestic purposes. There are 12 such wells at Greeley. The Pueblo basin is a similar one, and at present there are 8 wells therein.

West of Pueblo, at Florence and Cañon City, along the drainage basin of the Upper Arkansas, several heavy flows of water have been struck in boring for oil wells. The supply is used for irrigating purposes, the flow of which it is estimated will serve 100 acres. The most remarkable basin found in Colorado is situated just outside and west of the line of this investigation. Within three years, and largely during the past year, over 2,000 flowing wells have been sunk in the San Luis Valley or basin, which contains 16,000 square miles, and has an average altitude of about 7,000 feet. Surrounded by ranges of the highest mountains on the continent, whose sides inward to the basin are extremely precipitous, a vast drainage pours down into the coarse gravel and sand found just beneath the alluvium soil. Flowing water is struck at from depths of 60 to 150 feet, and a small number of wells have been bored to a greater depth. The cost is from $25 to $100 per well, and the flows are from 25 to 100 gallons per minute. The deepest well, in the center of the basin towards the east, has gone down nearly 1,000 feet. The heavy, permanent flows are unquestionably from the deepest wells. The water is used most extensively for domestic and stock purposes, but a considerable number of the farmers are now entirely dependent for their irrigation supply on these wells. In the village of Monte Vista there are some 90 wells. The Empire farm at Alamosa is supplied by 40 wells. It is probable that from 10,000 to 12,000 acres of land were wholly or partially irrigated by these wells during the past season. No diminution of flow has been perceived.

In the Territory of New Mexico attention is now being turned to the question of artesian wells. A few flows have been struck by the drill, but no large supply has yet been obtained. Professor Carpenter feels assured, however, that artesian basins of considerable value will be developed in New Mexico.*

* Since this report went to the printers, information has been received of the successful sinking of the first artesian well in New Mexico, six miles south of Springer, Colfax County. The flow was reached on the 19th of July, 1890, at a depth of 250



Well-boring near Florence, Colorado.

In San Luis Valley. Drive or Shallow-bored Wells Machinery.

Upon the *mesa* or table-land, westward of the Organ Mountains, which forms part of the famous Mesilla Valley, so prolific and valuable as a fruit-bearing region, there seems to be little reason to doubt that with proper experimenting artesian water may be developed to a large extent. The great feature of eastern New Mexico, to which the attention of the investigation was turned, is the hundreds of valuable springs, many scores of which are remarkable for size and volume, found within the foothills of the Pecos drainage basin, throughout the whole region of the east thereof and extending southeastward into central Texas. The time at the disposal of the field staff did not permit, however, a proper examination of the region.

A VALUABLE REPORT FROM WESTERN TEXAS.

The report made by Field Agent F. E. Roesler in relation to the artesian waters and other subterranean supplies of Texas west of the ninety-seventh meridian is the most minute of all that has been presented. It will bear careful inspection. Nearly 700 flowing wells are referred to, of which a large number is reported upon. These wells flow from 1 to 1,000 gallons per minute, and vary in depth from 15 to 1,852 feet, and in cost from $25 to $7,200. The average flow is about 15 gallons per minute. The five wells at Waco flow jointly the enormous volume of 5,000,000 gallons per day. A notable feature of these Waco wells is that the water-bearing stratum is found at a depth of at least 1,200 feet below the level of the Gulf of Mexico. The greater number of the wells reported is found between the 97th and 100th degrees of west longitude. From the 100th to the 103d degree there are but few such wells. West of the 103d meridian the supply of water from this source is larger. A remarkable feature of the section of Texas investigated is the supply of subterranean water from springs, among them being some of the largest known in the world. At Lampasas, in the central portion of the State, from one spring a flow of 2,400,000 gallons is obtained every twenty-four hours. The line of the subterranean waters moves westward from Lampasas, slightly to the north, bending at the 103d and 104th degrees directly north by west, entering through the Panhandle and joining that portion of New Mexico which has been referred to as showing a remarkable outburst of springs. To the eastward and northward of this line that portion of Texas rises abruptly for 500 or 600 feet, and flows north like a sea, forming what is called the Staked Plains. Mr. Roesler's view of the wells developed and the use of the water thereof in horticultural pursuits demands careful attention. The speculative references he makes as to the existence of undersheet or flowing water below the surface deserve the consideration that belongs to the views of a careful observer of large experience, knowledge, and good judgment to sustain his deductions. His whole report is one showing not only remarkable industry, but it is replete with information clearly presented, which illustrates in a striking manner the extent and importance of the supplies examined.

HORTICULTURE AND IRRIGATION.

Irrigation by means of wells and other underground sources has nowhere received so practical an illustration as in California. Quite re-

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feet. The volume thereof is estimated at 220 gallons per minute. Several wells have been bored at Springer, but the flow in them is of the negative character, as it does not rise above the surface. The altitude of this well is nearly 5,660 feet, or about 100 feet less than that of Springer. The drill passed through 20 feet of alluvium and 200 of slate and limestone. The water was struck below a stratum of sandstone 30 feet thick. The pressure is unknown at this office.—R. J. H.

cently a statement has been made by the postmaster at Sacramento, Russ D. Stevens, who is also a viticulturist, as to the effect of irrigation by wells in increasing both the quantity and quality of his grapes. The Sacramento Valley region of California has been considered for horticultural purposes as one in which irrigation was not necessary. Mr. Stevens, in 1888, bored two moderately deep wells and found water, a strong flow of which rises near to the surface, and is then distributed over the vineyard and orchard by windmill pumps. The result of his first year's work—that is 1889—was the doubling in value of his grapes as measured by sales in the New York market, and by almost the same increase in quantity. This is but one instance of hundreds that could be cited.

On the Staked Plains of Texas, where irrigation must be entirely by well water, fine fruits are grown with great advantage. The small farms thus irrigated at Marienfeld, Midland, Odessa, and Big Springs make handsome profits and return to their owners from $200 to $300 per acre. It is claimed also for the whole of subdistricts Nos. 1 and 2, in the Texas division, that owing to advantages of climate all the finer garden vegetables and small berries can be grown and ripened therein several weeks earlier than in southern California. The same thing is claimed as true of the entire southern and central sections of the Rio Grande Valley. Eastern New Mexico will be found to be a fruit-growing country of great possibilities. Outside of the valley of the Pecos, in which a large area is now cultivated by water from the canals fed by the great springs at Roswell, a large proportion of the arable land will be found in small isolated valleys readily served by the springs and underground supplies that are waiting to be utilized.

The foot-hills region of eastern Colorado, and the western portion of the Upper Arkansas Valley, so far east as Dodge City, Kans., will produce the fruits and berries of the temperate zone in great abundance and early maturity. All of these products can be greatly aided by the application of water to the soil—in the regions named irrigation is a necessity. A great portion of that land is still the property of the United States or of the State of Texas. There remains of public lands still unsurveyed,* in the State of Colorado, 8,500,000 acres; in New Mexico, 30,000,000; in Indian Territory, 13,500,000; in Public Lands strip, 3,672,640 acres; while in western Kansas and Nebraska there are at least 30,000,000 acres of unoccupied public lands, the greater portion of which, if water could be obtainable, can be made fertile and productive.

THE FLOWING WELLS OF THE BASIN REGION.

In Utah about 2,000 bored wells† have been sunk into the higher water bearing stratum of the Salt and Utah lakes' region. These wells rise through small bore pipes, from 1½ to 3 inches in diameter, with a flow of from 2 to 5 inches above the casing. No records of any value have been kept as to the service their waters render. Evidence

*American Almanac for 1888.

†Mormon church records give the location of 1,734 flowing wells. Prof. M. E. Jones, of the Deseret University, in a report made to the Governor of Utah for the use of the United States Senate Committee on Irrigation and the Reclamation of Arid Lands, places the total at the higher figure. The church report was made to Prof. F. H. Newell of the United States Irrigation Survey. The number of acres irrigated are reported by Newell at less than 2,000; by Professor Jones at the figures given in this paragraph.

ARTESIAN WELL AT BATTLE MOUNTAIN.

goes to show that no diminution of pressure has yet occurred. The water is used for stock and domestic farm purposes, also for meadow flooding in the Mormon settlements of the Jordan Valley and Utah Lake basin. From 8,000 to 10,000 arable acres, otherwise arid, are reclaimed by these wells. The possibilities of the irrigation of land in Utah by such wells, though necessarily limited, in no wise approach exhaustion. Deep wells flowing with high pressure have not yet been obtained. Every great mountain basin, the summits of whose surrounding peaks are cloud and snow gatherers, will be found to bear in the bowl of the basin, the drainage thereof.

In Nevada with its average altitude of 4,500 feet, and its mountain ranges rising from 6,000 to 11,000 feet above the level of the sea, the existence of large springs, many of them highly mineralized, is everywhere apparent. The attention of ranchmen and farmers in that State has been turned to the possibility of obtaining artesian water by well boring. There are now some sixty-seven wells in Nevada, flowing from 60,000 to 1,000,000 every twenty-four hours. The Board of Reclamation Commissioners in that State, declare the possibility of reclaiming, by means of such subterranean waters as will rise through wells or can be utilized from springs, not less than from 6,000,000 to 8,000,000 acres of fertile land. In Nye County, whose climatic conditions are semi-tropical, it is asserted that artesian waters will be readily obtained and be extremely valuable for reclamation purposes. If so, sugar, cotton, and other semi-tropical products and fruits, will be raised there in abundance. Over a considerable portion of Arizona, though no artesian waters have yet been struck by the wells bored, there are reasonable grounds for believing that such will be the case, and that such supplies can be obtained after examination by competent geologists and engineers. More than one lost or sunken river, like the Santa Cruz in southern Arizona, is known to exist. There are large stretches of country in which water lies so near to the surface as to create what the Mexican people call *cienegas*. In the San Simon Valley, for example, a broad grassy table-land stretching for miles between two great ranges, water in large quantities can be found almost anywhere from 8 to 30 feet below the surface. Crossing into southwestern New Mexico, and over its high bench-land or *mesa*, at Deming. where two great continental railroads meet, and of which a few years ago, a great lawyer declared during a land suit, that its "only proper inhabitants were horned toads and scorpions," there is now to be seen a large community with a prosperous town in its center, surrounded with gardens and fields, the irrigation of which is supplied from wells bored to the depth of from 40 to 80 feet, the water being raised and distributed to the surface by means of wind-mill pumps.

CALIFORNIA ARTESIAN WELLS AND THEIR ECONOMIC VALUE.

California, however, prominently illustrates the extent of artesian water, and its economic value also. Mr. George F. Weeks, of San Francisco, who, as a journalist, is constantly engaged in gathering irrigation statistics and preparing them for publication, telegraphs as follows, under date of July 14:

> There are upward of 3,000 artesian wells in California, irrigating from one-quarter acre to 1,000 acres each. They exist from San Diego to Shasta County, and while their flow is not one-tenth utilized, probably 60,000 acres are at present served. Their possible development in arid regions is almost illimitable.

At present the developed basins of that State are—

Those of the high altitude areas, such as that of Sierra County, where 200 wells are already flowing;

Those of the great Central Valley, or intra-mountain plain of Sacramento and San Joaquin;

Those of the San Francisco Bay region extending from the southern end of the bay, in a triangular shape down the coast to an apex at San José;*

Those of the coastal region south from San José with its table-lands, valleys, foot-hills;

Those of the extreme southern counties of Los Angeles, Orange, San Bernardino, and San Diego, including also the desert and plateau lands of the Colorado Basin, the Mojava Desert, and the Antelope Valley.

Thousands of bored wells are in existence, the water of which rises nearly to the surface, and myriads of wind-mills can be seen all over the landscape engaged in pumping this water for the use of farm-yard and field. A very considerable area, of which no direct record has been made, now in use for garden and orchard purposes, is maintained in fertility by water drawn from this source. In the southern coast counties these wells are very numerous. The drainage waters of the coast range are also tapped in the low rolling foot-hills by the enlargement of the springs or the driving of small tunnels therein. The California fruit-grower is just beginning to apprehend the importance of this supply. Two of the more important artesian belts known to the world are found in the San Joaquin Valley and in the counties of the State south therefrom. Tulare and Kern Counties offer interesting facts. The vast bulk of Mount Whitney towers over the Sierras to the east thereof, forming the central point of that enormous range, and sending down surface strata, and 80 to 100 inches of precipitation which annually falls upon its summit. The swollen floods of the King, Kern, and smaller streams in their turn supply the great canal systems of Kern and Tulare. Tulare Lake is fed from this source. The whole of that section of California's great valley will doubtless be found when proper investigation is made to be underlaid with the same supply; and in a belt of country lying to the north and south of Tulare

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* Mr. Brainard, C. E., in a paper before the American Society of Civil Engineers (March, 1887), describes the basin. In a discussion before the American Society of Civil Engineers, consequent upon the reading of a valuable paper on "Irrigation," by Edward Bates Dorsey, C. E., Henry A. Brainard, C. E., of California, spoke of irrigation by means of artesian wells, as follows:

"I have observed * * * in a section of country of triangular shape, the base being the southern end of San Francisco Bay, and the apex a point a few miles south of the city of San José. Within this district artesian water rises from 2 to 20 feet above the surface. The wells are from 4 to 7 inches in diameter, cased with iron, and capped at the top with regulating stop-cocks, or valves, by which the supply may be entirely shut off.

"Surrounding this district is still another, in which water rises to the surface only, or within distances down to 50 or 60 feet, the wells being from 100 to 200 feet deep.

"In the artesian belt 'proper' the wells vary from 100 to 500 feet. One well irrigates from 10 to 25 acres of land. The wells are bored along the highest side of the land, the overflowing water being conducted in wooden flumes laterally, and distributed as are any irrigation."

Mr. Brainard says that the water is used for gardens, small fruit orchards, alfalfa, and late or fodder-corn. Where the water does not flow above the surface; pumps are used. A small engine raises sufficient water each day to irrigate 5 acres. On the once-a-week application plan, much used in that section, it will irrigate 35 acres. According to Mr. Brainard, "the advantages of irrigation by artesian wells are: Absolute control of the water as to the amount, and also as to the time when it may be used. No complication (as to rights) can arise. As artesian wells have multiplied, there has been a reduction of head from 2 to 4 feet within the last twelve years."

A Seven-inch Bore Artesian Well, 450 Feet Deep, Paige and Morton's Ranch, Tulare, California.

Lake, some 40 miles in length and 50 in width, over one hundred flowing wells have already been bored.*

South of Tulare and in Kern County this belt or a similar one runs north and south for a distance of 50 miles and from 10 to 15 wide. In the Tulare basin the average depth of forty of the principal wells is 469 feet, and of the remainder about 300 feet. At that depth they are considered to possess the best and strongest flow. The lowest flow for twenty-four hours is 200,000 gallons and the highest 3,000,000, while the average is about 1,600,000. In the center of the tract, which contains the strongest wells, an area of 18 by 14 miles, the total flow is estimated at over 48,000,000 gallons per twenty-four hours. It is stated that 2,400 gallons flowing continuously for the season of one hundred days will irrigate 1 acre of land. If the water from the wells producing this flow was properly stored, it would, allowing the loss of one-third by evaporation and percolation (which for well water is a large estimate), irrigate at least 42,000 acres of land. There are now from 10,000 to 12,000 acres served by the Tulare County wells. Of 40-acre farms, 4,000 could easily be supplied from this tract without pumping or other mechanical means of lifting. A flow of 6 inches over an 8-inch casing, which is a common feature of these wells, will give 5 acre feet every twenty-four hours and serve 350 acres of land. The Kern County belt is even more remarkable. The able engineers, who have been employed by Messrs. Haggin and Carr, owners of the great canal system, estimate that the artesian underflow will cover the entire valley region, a tract of country as large as Delaware and Rhode Island combined, and capable of sustaining by agriculture a much greater population than those two States. The average Kern County well will serve, it is estimated, one section of 640 acres of land. If its continuous flow is properly stored, its service can be made as high as 3,500 acres. If these estimates are correct, the Kern County artesian belt will become in its economic quality the second important in the world. So strong is the flow when the ar-

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* *Partial table of artesian wells in California.*

[Compiled from "Physical Data and Statistics," State engineer's office, 1889.]

CENTRAL VALLEY.

Counties.	No. of artesian wells.	Depth of wells above sea-level.		Diameter of casing.	Average flow in gallons per 24 hours.	Total flow in gallons per 24 hours.
		Lowest.	Highest.			
		Feet.	*Feet.*	*Inches.*		
San Joaquin	12	920	1,250	7	315,000	*a*2,5[illegible]8,000
Stanislaus	19	270	1,000	7	101,300	*b*1,178,800
Merced	86	127	675	7	70,800	*c*2,768,000
Tulare	101	214	928	7 to 10	442,450	*d*28,810,000
Fresno	24	150	910	6 to 7	150,400	*e*3,105,900
Kern	36	180	630	7 to 9	790,150	*f*6,562,600
Sacramento	19	60	2,160	2 to 10½	....	....

(*a*) The flow of three wells not given. (*b*) The flow of five not given. (*c*) The flow of eight not given. (*d*) The flow of twelve not given. (*e*) The flow of six not given. (*f*) The flow of seven not given.

SOUTHERN COAST VALLEYS.

San Bernardino	407	40	416	1½ to 7	233,150	*a*12,992,504
Los Angeles	40	40	254	7	511,950	*b*9,095,900

(*a*) The flow of one hundred and ninety-eight wells is not given. These may be assumed with fairness to give enough flow to warrant an estimate of 24,000,000 gallons for each twenty-four hours for the whole four hundred and seven reported. (*b*) The flow of eight not given.

tesian supply is struck that the farmers find it difficult to control the same.

In the upper part of Kern County, just south of Tulare Lake, there are about forty of these great wells within a radius of 10 miles, none of which yields less than 1,000,000 gallons per day. The twelve largest, whose flow ranges from 1,200,000 to 2,500,000 gallons, give a total flow each twenty-four hours of 23,600,000 gallons, which will serve at least 20,000 acres. The temperature of this water is almost uniform, being about 71 Fahr. both winter and summer. The average depth of the upper or northern wells is about 350 feet, ranging from 250 to 460 feet. Elsewhere the range is from 325 to 1,000 feet in depth, the cost running from $500 to $3,000 and averaging about $1,400 each. The first of these wells was bored about twelve years since. Their use has been largely confined to the cultivation of alfalfa and other cattle feed. There are probably in the same region 500 or more bored wells, the water of which, derived from stratum near the surface, does not rise thereto but is lifted above it by mechanical means. Perhaps the most remarkable well from the stand-point of economics is one in the neighborhood of Deland, in the eastern part of the foot hills regions of Kern County. It is located on the southeast quarter of section 4, township 25 south, range 25 east, and for several years has flowed steadily to the amount of 2,500,000 gallons per day. It feeds an irrigation ditch of many miles in length and of considerable depth and width, which has the appearance of a small river. Kern County has been controlled chiefly by large land owners, whose interest now compels the adoption of the colony or small holdings system. With the increase of this form of settlement there will come a rapid exploitation of the underflow water supply, and more specially that the surface canal system, which has been created at the expense of several millions of dollars, will probably for some time remain in private hands to be used as a means of obtaining a large rental income. Prosperity on the part of the settlers will compel them to seek independence from this control, and as a result the great artesian underflow will be rapidly utilized.

WHY THE SUPPLY SHOULD BE BOTH PERIODIC AND PERMANENT.

Los Angeles and San Bernardino Counties have made great progress in the development of artesian waters. The stratum below the alluvium or surface soils is largely composed of glacial drift, coarse gravel, bowlders, clay, rocks, etc., that have been loosely forced down in enormous masses by the movement of glaciers. The drainage of the surrounding ranges finds its way into this loose drift, and as the hydrostatic pressure is necessarily great, the drainage sheet moving with slow momentum to the sea becomes at once, whenever tapped, an artesian flow of great force. There are several hundred springs in the eastern and southern portions of Los Angeles County and in the valley of Santa Ana; in fact, a great portion of the enormously valuable horticultural region of that county is supplied with the water it needs from this underground sheet. The value of such supplies, with the works by which they are utilized, runs into millions of dollars. In San Bernardino County the artesian basin supply forms one of the first, if not a most important source of irrigation. In the San Bernardino basin proper, conveyed by the drainage of the mountain range so known, there are not less than 2,000 flowing wells in operation. Land formerly held at from $10 to $40 is now salable at from $200 to $500 per acre. The use of such wells is comparatively recent. At first they were sunk

so rapidly that there was an alarming decrease in the supply. The effect of the care which followed is to establish the existence of periodicity. The wells increase and diminish in their flow with seasonable regularity, the melting of the snows of the mountain ranges filling the stratum from which the supply is derived. As a consequence, necessity is creating rules and regulations by which the flow is turned off or on, at stated intervals, and thereby economized to the utmost. The experience of San Bernardino and other portions of the fruit-growing sections of southern California, where wells are utilized for horticultural purposes, shows the need of maintaining public or community supervision over the sources of supply. The well-bore is usually private property, but in the arid region the source from which this supply is derived, must be under public control. The local body, State, county, or irrigation district, as the case may be, must therefore have power to determine the number of wells that can be profitably sunk so as to make the largest and most secure use of the supply. The experience of Denver, Colo., as illustrated by Field Agent Carpenter in his report, is an evidence of this necessity. With such public or community control, as suggested, a sufficient number of wells could be maintained in that basin in all probability to supply the demand. In southern California there are now over 2,000 flowing wells. A partial record of those sunk in the Chino Ranch, San Bernardino County, sent to this office by Richard Gird, the owner thereof, gives the following result:

No of wells.	Time completed.	Cost.	Location.				Remarks.
			Sec.	Tp.	R.	Meridian.	
1	1887	$329.86	9	2 S.	8 W.	S. B. M.	Soft, cool water found in heavy gravel, about 170 feet.
2	1887	854.40	3	2 S.	8 W.	S. B. M.	Soft, cool water found in heavy gravel, about 360 feet.
3	1887	1,039.66	13	2 S.	8 W.	S. B. M.	Soft, cool water found in heavy gravel, about 260 feet.
4	1887	478.16	4	2 S.	8 W.	S. B. M.	Soft, cool water found in heavy gravel, about 300 feet.
5	1887	1,917.50	4	2 S.	8 W.	S. B. M.	Soft, cool water found in heavy gravel, about 360 feet.
6	1888	2,375.00	33	1 S.	8 W.	S. B. M.	Tools lost at about 600 feet and well abandoned.
7	1888	877.20	7	2 S.	7 W.	S. B. M.	Struck impenetrable bowlder at 100 feet and well abandoned.
8	.....	469.35	17	2 S.	7 W.	S. B. M.	Still unfinished.
9	1888	935.63	4	2 S.	8 W.	S. B. M.	Flows over 40 inches choice water, about 300 feet.
10	1888	1,067.32	4	2 S.	8 W.	S. B. M.	Flows over 40 inches (near No. 9), about 300 feet.

NOTE.—The above wells are partly 7 and partly 9 inch casing.

Owing to the nature of the stratum the cost of sinking such wells as these on the Chino Ranch is no evidence of the cost of the labor employed, though it may be of the pipe and casing used. The bowlder character of the stratum is such that a well of 500 feet in depth will often cost no more than one of 100 feet. Two of the best wells on the ranch, sunk to 102 feet each, have a strong flow in a 2-inch casing, and have cost but $125 a piece.

The most important single use of wells in San Bernardino County, however, is that of the Arlington Heights addition to the famous Riverside colony. Matthew Gage, the owner of the said land, purchased 2,000 acres in the valley of the Santa Ana River, ranging on both sides thereof, and sunk thereon forty-two artesian wells at a depth of 150 to

500 feet. The water of these wells flows to and is stored in a system of distributary canals. Mr. Gage has reclaimed from the elevated mesa land lying above Riverside 2,430 acres, now under orange and raisin cultivation. Each acre of this land will sell at from $200 to $500. In an examination by Prof. E. W. Hilgard, of the University of California, perhaps the best authority in America on the relations of the soils and water to irrigation and cultivation, some deductions are published bearing upon the degree of interdependence found in such wells. Professor Hilgard finds that the nature of the sub-strata of the valley wherein the wells are bored to be entirely favorable to the permanence of the supply. After describing this sub-strata, and the sources of the water which flows through it, Professor Hilgard says:

What we now see happening during the rainy season at the mouths of the cañons has happened from time immemorial; the original depths of the San Bernardino Valley has been filled up to within 20 or 30 feet of the present surface, with just such masses as we now find surrounding the mouths of the cañons; this immense mass is filled with water, annually replenished during the flood season by the absorption of a portion of the water, issuing from the mountain, the rest passing directly to the sea.

The Santa Ana River issues from its cañon about 12 miles above the head of the Gage Canal. By barometric measurement it descends about 700 feet in that distance, while Mill Creek issues several hundred feet higher still. The water absorbed by the gravelly masses and afterwards confined between successive clay sheets, might at the head gate in a well 200 feet deep, be under nearly 1,000 feet of pressure from the head of the valley. No such degree of pressure can, however, manifest itself because of the enormous friction opposed to any movement, and doubtless also because of a steady though slow seepage towards the sea, which relieves it below. It is this steadily moving column that the artesian auger intercepts and taps; and the question naturally presents itself whether and to what extent bore holes made in the lower part of the valley would be likely to deplete those located higher up as would ordinarily be expected.

While in the absence of more exact data, a close calculation in the premises is not possible, the observations made in regard to the effect of wells and groups of wells upon each other's flow suffices to show that such depletion is not at all likely to happen; on the contrary, under existing conditions, it is probable that the bore holes tapping the slowly-moving column higher up the valley will, when tapping the same water-bearing stratum, have somewhat the advantages of those located lower down. But as the latter are more likely to reach the lower portions of the water-bearing mass, and as the extent of that mass is so great, it is not likely that the calls made upon the great stock will for some time to come be such as to create serious interference. This conclusion is the more probable, as in the case of any material lowering of the water level at the head of the valley, the absorption during the flood time would doubtless be increased in a certain ratio to that lower level, and a larger proportion of flood waters would be stored instead of rushing uselessly to the sea. To some extent, therefore, the increased demand would doubtless be offset by an increased supply.

THE WORLD'S USE OF ARTESIAN WELLS.

The modern methods of boring for artesian water did not come into existence until the beginning of the present century. The French Society for the Encouragement of Agriculture, in 1818, was the first mover in that direction, and since then the improvement has been most rapid. The Chinese still pursue the ancient method of percussion in the boring of artesian wells, and they have followed it for more than three thousand years. The utilization of under-ground water is a leading fact in the history of oriental regions, and its importance can be realized by an illustration from one country alone: The plateau, or high table-land region, which forms the greater portion of the peninsula of Arabia is without a single perennial stream or body of surface water. A population of 12,000,000 resides therein; large quantities of wheat, durra, barley, millet, beans and tropical fruits are grown on this high, apparently dry, sterile plateau. Ninety per cent. of the water supply, which

LOW-PRESSURE ARTESIAN WELL, SOUTHERN CALIFORNIA.

produces the present fertility, is drawn from below the surface by means of old bored wells, and deep wells or tanks that are dug into the surface of the soil, some of them to a great depth, partly cased with timber or clay, into which the water pours by seepage or percolation from the surrounding earth, and is then drawn to the surface by the old-fashioned wheel and bucket the power of which is furnished by camels or asses. The Mohamedan population of this peninsula is but little known to the traveler. Palgrave and others, who have visited them, speak of the comparative comfort and prosperity they enjoy. They are among the most intelligent and moral of their faith. That a much more abundant life was once seen than now exists, is evidenced by the remains of great cities which have been found. In the southern portion of the peninsula, and approaching the Indian Ocean, springs abound, the water of which is drawn off into tanks, or wells, as they are called. They are thus kept from loss by evaporation; to be distributed by means of well-sweeps to the thirsty soil. In a more northerly portion, the only supply comes from cisterns in which the winter torrents are stored. The striking fact in all of Central Arabia, however, is that of under ground supply. Throughout the eastern part of Oman, on the Persian Gulf, and especially in the villages of Kaseen, as an illustration of the character of these supplies, it may be stated that there are 40 wells, the flow from which maintains a population of between 25,000 and 30,000 persons. The depth of these under-ground supplies ranges from 15 to 200 feet.

EAST INDIAN IRRIGATION BY WELLS.

In British India the system of irrigation by wells is carried on most extensively. Sir James Strachey, in his great work on the Finances of India, some years since, placed the area of cultivated land at 200,000,000 acres, of which 28,000,000 acres were cultivated by irrigation. Of this total, about 12,000,000 acres were served by water drawn from wells, and generally by man-power, it being found that the use of the mot or bullock-well is too costly for that country of cheap human labor. The general verdict among engineers and practical administrative officials is that the land irrigated by well-water is more economically served than that irrigated by water from canals. Canal-water is, however, more fertilizing, having been exposed to the sun. The waste of water in canal use has been found to be so great in many portions of India that the engineers have commenced the work of lowering the canals, so as to compel the lift and distribution of water by mechanical means. This results in greater economy in its use. The 12,000,000 acres spoken of as supplied by well-water include, in the main, only the provinces directly under British administration. In the native states tributary to Great Britain, the number of wells and village tanks, which are usually large excavations designed to secure the seepage and underflow water, and of the drainage of elevated ground in the neighborhood, is much greater. It has been estimated that the area covered in the Indian peninsula by well irrigation is not less than 20,000,000 acres. From accessible statistics of eleven districts, including Madras and the Punjab, allowing 10 acres for each well, 392,593 are reported, serving 3,925,930 acres. The British Government, since the famine period, has given great encouragement and attention to the system of village wells and community tanks, allowing bounties for their protection, and providing careful regulations for their maintenance. They have found it cheaper and wiser to assist in securing a permanent supply of water so as to prevent famine, than to feed the people after the famine comes.

ASIATIC USE OF UNDER-GROUND SUPPLIES.

In Sind, Beloochistan, Cashmere, Afghanistan, Persia (especially the Plateau of the Iran region), Chinese Turkestan, and in Russian Turkestan, under-ground waters and their restoration to the surface by gravity or lifting have always played a most important part. A vast system of under-ground conduits exists throughout the regions named, especially in Persia, that are designed to carry the drainage waters of the foot-hills regions for long distances until they debouche upon the less elevated plains below. So enormous is this supply, that vast populations have, for many centuries past, been supported from the fields that were quickened by the application of such waters. The proofs of their enormous extent are found throughout the whole of Central Asia—the great plateau and hill country which belongs to the Himalayan system. It has been suggested by observers traveling through Persia and elsewhere that these karnaks or under-ground conduits have the effect of desiccating the soil above the area of their influence as they pass from foot-hills to the plains. This, if true, is probably due to the clumsy character of the system, and not at all to the endeavor to secure the utilization of the under-ground drainage waters. As an illustration of the nature of the subterranean water-supply, the evidence of Civil Engineer J. W. Barns, a former member of the Bombay public works department, who was stationed some years since in Beloochistan and the hill district of western Sind, may be taken. He says:

> I had long entertained the idea that subterranean water existed in certain localities in the hills capable of overflowing through artesian borings, if they were made, and in 1885–'86, I determined, after a critical examination, to give this mode of obtaining water a trial.

Mr. Barns's labors were commenced about 8 miles northeast of Kurrachee, and in the course of a few weeks he was able to pierce the first water-bearing stratum, "when the water rushed up and overflowed the surface, continuing without intermission to flow to this day. The temperature of the water is 83 Fah." Though slightly brackish, it is useful for irrigation. Mr. Barns regards the large springs which abound in the district wherein he worked as proceeding from the same source as the artesian supply. At a lower depth he expected a larger and purer yield, and suggests a continuance of boring to the tertiary strata. This is the same which our geologists reported as underlying western Nebraska and Kansas. The description of the region in which Mr. Barns worked, climatic considerations aside, bears a striking parallel to the southeastern porton of New Mexico, in which there is a great spring section continuing south and east into the lower part of the Panhandle and other sections of Texas. Mr. Barns says in relation to the general subject of subterranean supply:

> In dealing with this question, we start with the absolute certainty that wherever water is found inland, whether in the shape of springs or rivulets, it has but one origin, namely, the supply from the clouds in the form of rain and snow. We are in the habit, because some large portion of those zones just beyond the tropics contains vast deserts, and have no rivers draining toward the ocean, of assuming that there is literally no rain-fall; but it is a mistake; even the Sind, which is spoken of as being destitute of rain, has gauged a rain-fall of forty inches in some parts in three months, and averages, I believe, four inches per annum.

The value of local irrigation is shown by the Indian revenue reports. The land irrigated by wells in the Madras Presidency, being about 2,000,000 acres in extent, yields a revenue of £1,500,000 sterling, or $7,500,000, against the $10,000,000 derived from 25,000,000 acres of non-irrigated farm land. In one case the land revenue or rent is $6.75 per

acre, against \$2.50 per acre in the other. The intrinsic or market value of crops from irrigated lands will average \$8.50 per acre as against \$2.50 in the non-irrigated. The latter depends entirely upon the local rain-fall.

It is a fair estimate that there are in the world to-day at least 200,000,000 persons depending solely for their food upon areas irrigated by water drawn in the most primitive manner from underground sources in the form of wells, springs, or drainage conduits, such as have been referred to as existing in central Asia and Persia. An examination of the records, habits, and customs of the communities so supplied will show an elaborate system of care and maintenance. The countries in which this system has been most widely obtained have in past centuries been more highly civilized and have borne a large share in the ancient history of the world. They have not failed to maintain their position by reason of the failure of the water supply, but because of the ravages of war, the extent and proofs whereof are seen on all sides, which have devastated and destroyed their fields and works. In the past history of this vast portion of the world the people of whole States have been swept out of existence. The constant and unchanging tendency of climatic aridity has conquered the ameliorations produced by human industry, filled up the conduits, choked the wells, destroyed the surface works, and from want of the cultivation theretofore existing produced and intensified the vast desolation which now exists over such large areas. The re-establishment of the irrigating works and the conservation of the water supplies required therefor, will quite certainly restore enormous portions of these great areas to the use of man. If such things can be done under the tropical sun they will certainly be achieved in our more favorable climatic conditions and through the quickening activity of the mechanical and inventive genius of our people.

AUSTRALIAN INVESTIGATIONS AND EXPENDITURES.

The British colonies of New South Wales, Victoria, South Australia, and Queensland are actively interested in the problems of artesian or other subterranean waters. Considerable sums have already been expended directly by these colonial governments in boring for well water and in the construction of tanks to store the waters of percolation. Bounties are given in aid of private enterprise, and "trust" organizations have been framed to enable the "shire" or county authorities to issue bonds, construct works, bore wells, store water, and provide for their conservation and distribution. Besides the direct encouragements, these Australian colonies annually expend large sums of money in investigation and in the publication of the results of the same. The irrigation reports of New South Wales and Victoria are among the best and most instructive issued in the world. It is said by one of the scientists employed by the colony of New South Wales that 1 inch of rain over the whole colony at the right time is worth a million of money; that is, \$5,000,000 of our money of account. The average annual rain-fall for that colony is given for a period of fifteen years at 23.08 inches. The evaporation in 1888, as gauged at nine stations, averaged 47.72 inches, the largest annual loss known since observations have been taken. Other and interesting investigations relate to loss by drainage, and the conclusions reached are striking. Lake George is an important body of interior water. The water-shed area is twelve times that of the lake proper. The gauges in use show that on the occasion of a great rain-storm the lake waters arose exactly 11½ inches. Of this 8 inches were directly due to the rain-fall, the balance being drainage. If the fall of

the whole area had been conserved, the lake would have risen 96 inches. As it was the observations show an immediate loss by drainage of $84\frac{1}{2}$ inches. This proves a natural conservation into the lake through percolation of but $3\frac{1}{2}$ inches of the total precipitation. In the Darling River basin the drainage conservation during the wettest year of observations amounts to but 2.33 per cent. of the total rain-fall on its surface. These facts justify a belief in the enormous extent of existing and continuous underground supplies of waters to be made available for arable and pastoral irrigation. Several thousand flowing and rising wells are mentioned, and their use is given in the colonial reports.

RECLAMATION OF THE ALGERIAN SAHARA BY WELLS.

But the most remarkable example of reclamation by means of artesian well water is found in the desert provinces or departments of Algeria under the French rule. The area, officially given, of French Algeria is 184,465 square miles. The outlying portion is put at 135,000 square miles. In this total of over 329,415 square miles one half belongs to the Sahara or desert. The European population in 1887 was about 250,000; the natives and naturalized were 3,328,549, making a total of 3,5 8,549. Cultivation by the means of flowing well-waters has been sedulously fostered by the French Colonial Government for both political and economic reasons. Such wells as a means of reclamation began systematically to be bored in 1857, the French engineer, M. Jus, having demonstrated in 1856 that the desert was endowed with large supplies of underground water. The total number of wells that have been bored since that date in the departments of Algiers, Oran, and Constantine is stated at 13,135. These wells range from 75 to 400 feet in depth, and the low pressure common to the majority of them forces the water over the small bored casings to a distance of about 2 feet above the ground. The waters are then collected in small ditches, which convey them to the vineyards, date trees, and fields of durra, millet, wheat, etc., which comprise the chief products. In all, about 12,000,000 acres have been reclaimed in this way. The government bores are at least one-tenth of the whole number.

The total flow of 100 of these wells in the desert south of Constantine is given at 33,016,000 cubic gallons; that is, about 120,000 acre feet per year. As an illustration of the reclamation brought about by this well irrigation, the following figures from a report made in 1885 will be of value, but they relate solely to the cultivation of the grape for wine-making purposes. In the province of Algeria there are 60,322 acres; in Constantine, 25,021 acres; in Oran, 26,114. Under this species of cultivation Algeria is becoming a great wine-growing country. It sent to France during eleven months of 1886, 10,513,966 gallons of wine, and of cider in the same year, 219,277,124 gallons were made. The date palm is the largest product of the desert oases proper. The total area under colonization or settled occupation in 1887 is given at 49,400,000 acres; under cultivation by irrigation in wheat, barley, oats, vines, olives, dates, tobacco, etc., at 17,041,134. The forest plantations cover 5,000,000 acres. Mons. G. Rolland, in the Revue Scientifique of June, 1886, says in relation to the province of L'Oued Rir:

> Within thirty years the oases (reclaimed by wells) have increased in value five-fold; the condition of the natives has been improved, together with the complete pacification of the southern part of Algiers, and the population has more than doubled. These oases are composed principally of forests of date palms, the shade of which shelters the growth of their grapes. Without irrigation it would be impossible for the earth to yield anything, even the date palms would not produce fruit.

Algerian Artesian Well, 988 Gallons per Minute.

The manner of irrigation varies according to the nature of the water obtained. There are several kinds of oases, viz: those of the rivers, those with common wells, those with springs, and others with artesian wells; all of which kinds are combined at times in the same area. The river oases are found easily in the dry bed of the Oued, and the sunken waters of the stream are brought to the surface by excavation and boring. This supply comes from the "Mountains of the North." The usually dry streams become torrential at the spring season. Water is very scarce in summer and the oases suffer unless reservoirs have been made by means of dams.

The common wells of the Algerian Sahara are quite numerous, especially in the center of the region, but the prosperous sections are those regions which are supplied by artesian waters. It is not necessary that these waters should gush or flow above ground, for in some parts of the Sahara and the province of Constantine there is found a sheet of water reached from the surface at a depth of from 10 to 20 feet beneath. When tapped this supply rises rapidly. The area in which it is found is close to, and sometimes below, sea-level. The very gardens and vineyards that are cultivated by this supply are lodged in little cavities dug out of the soil between the sand dunes that cover the larger portion of the Souf region. By this means the palm roots itself in the watery bed found below, thus obtaining a constant though moderate humidity. The earth dug out forms a barrier around each of these little gardens, against which the sand accumulates, protecting the palms from being overwhelmed, and making at the same time a curious feature of the landscape, as their green plumes seem often on a level with the ordinary surface. Under these conditions the palm comes to perfect maturity. Many thousand acres are reclaimed in this way. In the artesian regions proper the water gushes forth with a small, but steady and permanent flow. The manner of using it in all sections is to distribute it in proper channels, it being constant at all seasons of the year. Within a few years past this system of artesian waters and distribution has penetrated eastward into the Sahara of Tunis, and considerable areas are there under cultivation by this method. A remarkable fact in the development of this supply is the enormous increase which has resulted from the systematic boring of wells and the distribution of waters. So large is the supply in some parts that *colmotage*—that is, draining with irrigation—is necessarily practiced to insure the security of the crops and the health of the inhabitants. The Sahara regions of southern Algeria and Tunis possess immense basins of artesian water, no doubt with high pressure, and flowing therefore with considerable force. The waters found are usually soft and potable, their temperature ranging as high as 70°. To the north and west of Constantine, there is an enormous springs region, among which may be reckoned the sources of the Zab, forty-two in number. In L'Oued Rir, already referred to, the united discharge of these artesian wells amounts to 34,346,000,000 gallons a year, or 213,714 gallons per minute. At the time of the French conquest of this region the condition of these oases was most lamentable. Cultivation was fading away from want of water, many of these oases had disappeared entirely under the sand clouds which are constantly blown across the surface of the Sahara, but now they are well cultivated.

The conservation of water by the Algerian system of well-boring and storage is strikingly illustrated by the following table of annual use and waste in acre-feet (325,829 gallons of water per acre, or 1 cubic foot upon the surface of an acre of land) at the village of Saint-Denis du Sig, near the River Maherru:

Date.	Waters utilized.	Not utilized.
	Acre-feet	*Acre-feet.*
1863	9,351	2,397
1864	8,893	5,955
1865	16,235	33,410
1866	10,485	....
1867	4,511	....
1868	13,594	7,489
1869	10,757	6,106
1870	10,250	3,644
1871	11,578	10,250
1872	16,485	18,385
Total	112,139	87,636

The first well was sunk in June, 1856. When the water poured forth it yielded 4,000 liters, or 1,040 gallons, per minute, and it was named the "Fountain of Peace." In 1885 there were 114 deep artesian wells bored by the French Government in that province. From 492 other wells in the same region the united discharge is 268,698 liters, or 69,861 gallons, per minute. The Government wells, some of which have been

in use for thirty years, have never decreased in their discharge; on the contrary, there is a rapid increase in the total water supply. In the Department L'Oued Rir these wells have been the means of reclaiming forty-three oases, which have about 520,000 date-palms in full bearing, 100,000 other fruit-trees, and 140,000 date-trees of seven years' growth. The annual value of such production exceeds $500,000, and the entire increase in value has not been less than fivefold. Since the commencement of the artesian waters exploitation the French Government has organized an extensive plan of colonization, which they are gradually extending southward, taking in areas that have been regarded heretofore as purely desert in character. By so doing they control the nomadic tribes about them, create new oases, and make settlements where nothing but waste existed.*

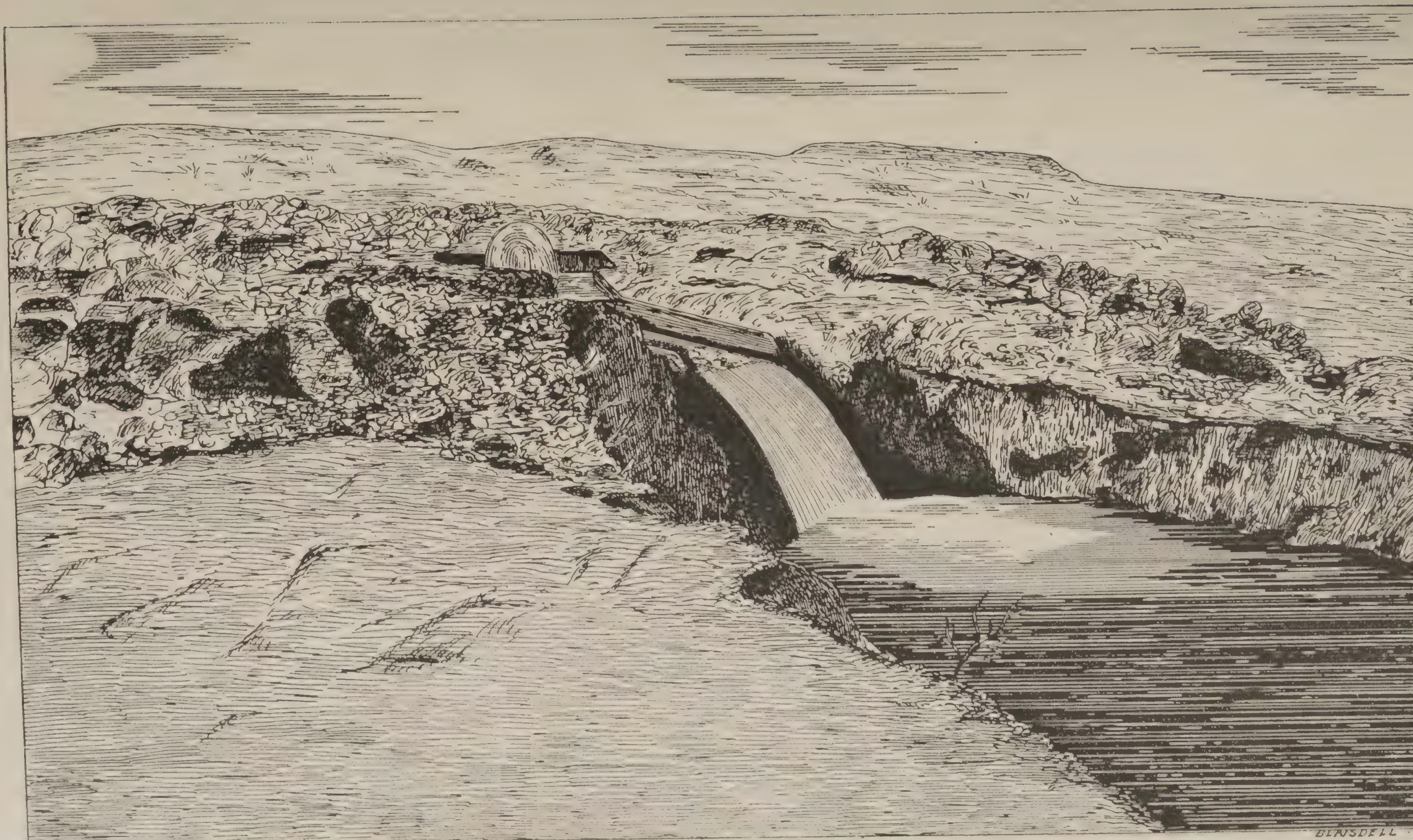
WHY SUCH UNDER-GROUND SUPPLIES EXIST.

The explanation of the Algerian supplies is very simple. About the desert rise precipitous mountain ranges, towering to a great altitude. The drainage of these mountains, now denuded of timber, comes down with great torrential force, disappearing in the sandy regions below. Where the water collects in basins at the foot of the mountains it soon evaporates under the influence of the summer heat. Disappearing below the sand, these waters give birth to subterranean sheets of water, which, according to the place from which they flow, and the hydrostatic pressure to which they are subjected, have more or less force on being tapped and rising to the surface. The utilization of the Algerian underflow offers a remarkable illustration of the great importance of such waters in their economic use. It would be to a majority of hydraulic engineers and geologists a most unlikely place in which to find such a supply. The existence thereof points to the possibility, indeed the strong probability, of our also finding abundant subwaters in such regions within our own territory, as the Colorado, the Mojave, and the Antelope deserts in California, as well as other desert basins elsewhere found.

There are other proofs to be given of the existence in enormous volume and body of the waters of drainage, seepage, and percolation throughout the known world. There is abundant proof also of their use and value in agriculture and horticulture, for power and domestic purposes. Spain, for example, has within the present generation developed a large artesian supply, using the same for farm cultivation, thereby in a more improved form returning to the practices of the Moors. In Italy a great area is influenced and aided by artesian waters. So also in Belgium, France, and Great Britain. Nowhere, indeed, have these subterranean waters, in some form or another, been a failure. Their development, then, is a matter of great importance. When successful they will bring the life-giving fluid to the earth's surface and quicken it into fertility. They will do this if the conditions are fully made clear to the common understanding, under circumstances sure to render co-operation easy and results somewhat uncostly.

* The following table gives the total (1887) of flowing and rising wells in Algiers and their cost:

Provinces.	Artesian and chain-pump wells.	Cost of construction.
Algiers	6,128	$16,280,861.20
Oran	4,384	15,062,408.80
Constantine	2,623	13,773,210.40
Total	13,135	45,116,480.40



Algerian Artesian Well, 1,560 Gallons per Minute.

CONCLUSION AND ACCOMPANYING REPORTS.

The provision of law under which the artesian wells investigation has been carried on distinctly and affirmatively directs that "nothing herein (contained) shall commit the Government to any plan of irrigation or the construction of works thereunder." In strict accordance with your instructions, and in obedience to both letter and spirit of law, this work has been carried on. No attempt has been made to support or find "any plan of irrigation." No expenditure could have been made for "construction works," and not a thought even has been given thereto. The object was to obtain information, and every energy has been strained in that direction and to assure the full reliability of the same. A considerable amount of correlative data has been of necessity secured in the work assigned to the gentlemen engaged in the investigation. This data has proved very useful in the preparation of the accompanying reports, and much of it will be embodied in a suplementary report called for by a resolution of the United States Senate. Whatever conclusions may be reached as to the need or otherwise of further legislation, this may be fairly said, that the facts presented fully justify present expenditures, and demand, because of their weight and importance, a full and serious consideration of the grave legislative, economic, hydrologic and other physical problems involved. They vitally relate to the present and future administration of a large section of our public domain; they are intimately connected with the industrial security of a large and growing population, and they greatly concern the conservation and progress of our western agriculture.

In closing this report, I have the honor to forward herewith the reports, submitted to the Secretary through the special agent in charge, of Edwin S. Nettleton, supervising engineer of the United States Irrigation Survey, of Prof. Robert Hay, general field geologist, and of the State geologist of Texas, E. T. Dumble. Also the reports made through Professor Hay, of the field geologists, to wit:

Prof. Garry E. Culver, on the Dakotas artesian basins and their geology.

Prof. Gilbert E. Bailey, on the artesian waters and geology of the southwest section of the State of South Dakota, and the eastern section of Wyoming.

Prof. Lewis E. Hicks, on the artesian and subterranean waters of Nebraska and the geology thereof.

Prof. P. H. Van Diest, C. E., on the artesian basins and waters of Colorado and the geology thereof.

Also the reports of the several division field agents made to the special agent in charge, to wit:

T. S. Underhill, on the wells and waters of North Dakota.

Prof. Stephen G. Updyke, on the artesian wells and basins of the southeast portion of South Dakota.

F. F. B. Coffin, State irrigation engineer for South Dakota, on the artesian wells in that portion of South Dakota east of the Missouri and north of 44° 13′ of north latitude.

Horace Beach, special expert, on the finding of artesian waters in the Dakotas.

J. W. Gregory, on the artesian and subterranean waters and wells of the central division, western Kansas, Nebraska, and Indian Territory, etc.

Prof. L. G. Carpenter, on the artesian basins, wells, springs, and other supplies of eastern Colorado and New Mexico.

Frank E. Roesler, on the artesian waters, wells, springs, and under-sheet supplies of Texas west of 97° of longitude.

The following maps and views also accompany the report:

I. Map of the region of investigation in three parts:

(*a*) North and South Dakota;

(*b*) Nebraska, Kansas, and public land strip west of the ninety-seventh meridian, with Colorado and Wyoming east of the one hundred and fifth meridian of longitude west of Greenwich; and

(*c*) The Indian Territory, New Mexico, and Texas, from the ninety-seventh meridian westward to the foothills of the Rocky Mountains.

II. Map of the Denver, Colo., artesian basin.

III. Photographs and views of wells, etc.

(*a*) At Woonsocket, S. D.

(*b*) The same, another view.

(*c*) Boring machinery for deep wells.

(*d*) Well at Huron, S. D.; discharge.

(*e*) The same, another view.

(*f*) View of gas pressure wells at Florence, Colo.

(*g*) In San Luis Valley, Colorado; drive or shallow well machinery.

(*h*) Well at Battle Mountain, Nev.

(*i*) Artesian well and lake at Tulare, Cal.

(*j*) Low pressure wells of southern California.

(*k*) Flowing well at Delano, Kern County, Cal.

(*l*) Algerian artesian well; in the desert.

(*m*) Artesian desert well in Algiers with date palms and distributing ditch.

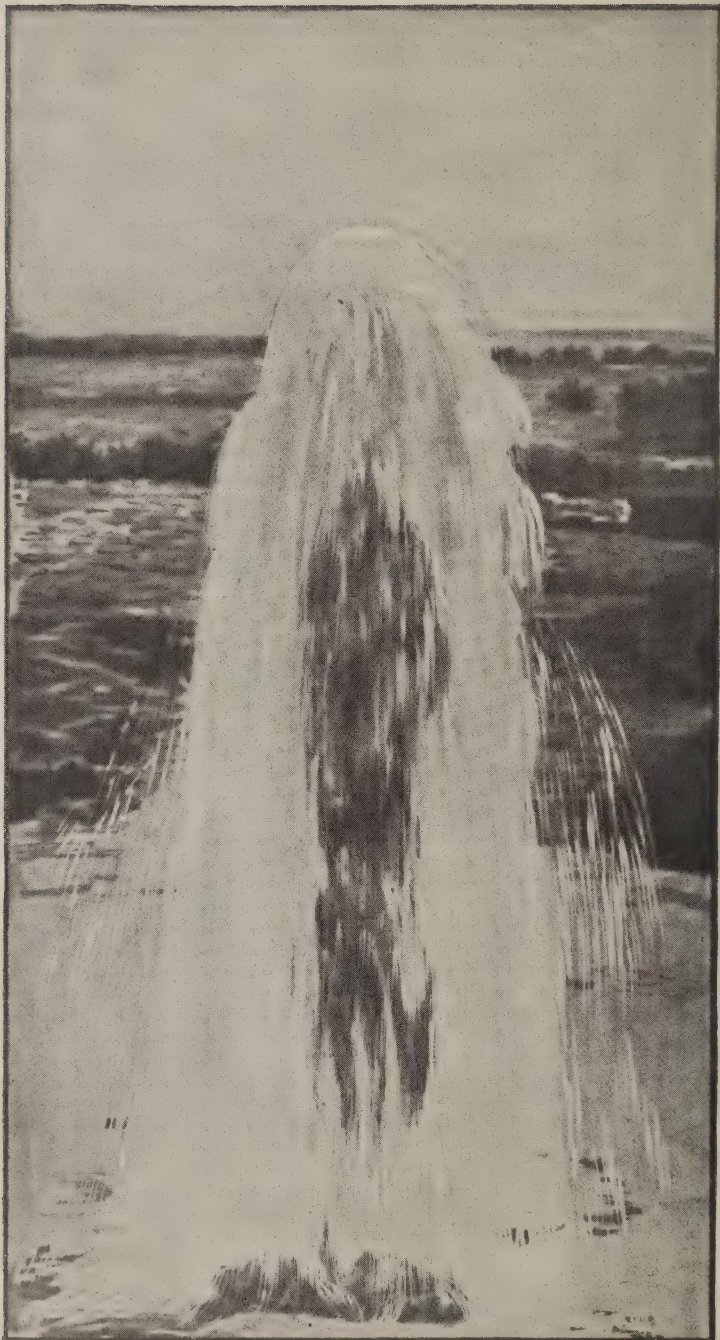
Tabulations of the wells and springs reported by the several field agents.

Certain miscellaneous data and information relating to artesian waters.

I have the honor to remain, yours, most respectfully,

RICHARD J. HINTON,
Special Agent in Charge.

The Honorable SECRETARY OF AGRICULTURE.



Flowing Artesian Well at Deland, Kern County, California.

2,500,000 gallons each 24 hours; 1,736 gallons per minute.

REPORT OF EDWIN S. NETTLETON, SUPERVISING ENGINEER, UNITED STATES IRRIGATION SURVEY.

[In charge of the field work of investigation.]

I transmit herewith my report as supervising engineer of the field work in connection with the artesian-wells investigation.

After the act making appropriation for the investigation was approved, considerable time was necessarily spent in organizing the work to be done in the field and in the preparation and printing of the necessary blanks, so that active duty was not begun in the Dakotas until about the 28th of April, and nearly one week later in other parts of the field on account of the non-arrival of blanks.

By the terms of the order requiring the work to be finished and the reports of the field agents to be in Washington not later than the 24th of June (which order was afterwards slightly extended), there were but about fifty working days, at most, in which to cover a country of about 1200 miles long by about one-third as wide. This has been done as well as it could be with the forces employed.

The investigation was divided into three branches—the statistical, the engineering, and the geological. The statistical is that branch by the agency of which the circulars and blank inquiries were distributed, and the field agents were charged with the work of sending out these blank inquiries and collecting and holding them for the use of the geologists, or forwarding them to Washington for compilation as they might be ordered. My own duty has been the supervision and direction of the work of the field agents and geologists, and the furnishing of the geologists such topographic and engineering data as they might require. The work of the geological branch consisted of making examinations of the outcropping rocks, and the inspection of the records of strata passed through by the artesian well borings, by the aid of which they might be able to determine the geological horizon with a view to ascertain, if possible, the existence, limit, and extent of the water-bearing stratum, or its non-existence, and to designate where water might possibly be found, and where, in all probability, it would be useless to bore for artesian water.

The work of collecting the statistical information was assigned at Washington as follows:

North Dakota to T. S. Underhill; the eastern portion of South Dakota east of the Missouri River, to S. G. Updyke; the western part of South Dakota east of the river, to Fred. F. F. B. Coffin; Nebraska, Kansas, and the Indian Territory west of the ninety seventh meridian and one degree of longitude of eastern Colorado, to J. W. Gregory; New Mexico, and Colorado lying east of the foot-hills of the Rocky Mountains, except one degree of longitude of eastern Colorado, to L. G. Carpenter; Texas west of the ninety-seventh meridian, to F. E. Roesler.

The geological work was assigned as follows: Eastern Montana, North and South Dakota, except the southwestern portion of South Dakota, to G. E. Culver; the southwestern portion of South Dakota

and Wyoming, to G. E. Bailey, who also acted as field agent for the same territory; Nebraska, to L. E. Hicks; Kansas and Indian Territory, to Robert Hay; Colorado and New Mexico, to P. H. Van Diest; Texas, to E. T. Dumble. Professor Hay was given by the Department general charge of all the geological work covered by the investigation, and in addition he has reported on the same data concerning Kansas and the Indian Territory.

The Department was very fortunate in the selection of the geologists as each had formerly made a professional study of the districts assigned them.

Mr. G. E. Culver, professor of geology in the State University at Vermillion, S. Dak., has not only made geological examinations of large portions of North and South Dakota, but he has, during the past two years, investigated the artesian well problem in those States.

Mr. G. E. Bailey, professor of the School of Mines at Rapid City, S. Dak., who was at one time the Territorial geologist for Wyoming, has recently made a geological study of a region of country in and about the Black Hills, South Dakota.

Mr. L. E. Hicks, professor of geology in the university at Lincoln, Nebr., and geologist for that State, has made a study of the geology of Nebraska as well as of the artesian and underground waters.

Prof. Robert Hay, of Junction City, Kans., has done considerable geological work in Kansas for the United States Geological Survey, and has also made an economic geological survey of a large portion of that State under the direction of the State board of agriculture.

Mr. P. H. Van Diest, of Denver, Colo., has not only done a great deal of geological work in Colorado and New Mexico, but has studied and written considerably about the artesian well problem in Colorado, especially regarding the Denver artesian basin.

Prof. E. T. Dumble is the present incumbent of the office of State geologist for Texas and has access to the records of said office.

In inviting these gentlemen to assist in this inquiry, the Department has not only secured their services but it has obtained from them a vast amount of previously acquired knowledge which is of great service to this investigation.

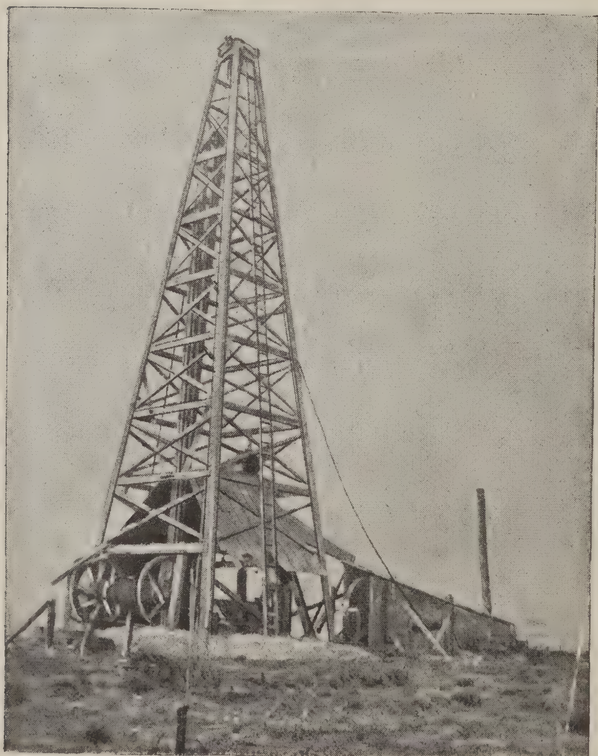
Upon taking the field it very soon became apparent that a topographical survey was unnecessary, as it would involve a needless expenditure of time and money. The country to be examined is traversed in all directions by railroads, and the elevations above sea-level of all the railway stations could be obtained by very little effort. The agents were supplied with aneroid barometers and were instructed how to determine the difference in elevation between the railway stations and the wells in their respective neighborhoods, by means of which information we shall be able to compare everything to one datum line, namely, sea-level. The adoption of this plan has given the geologists one point of reference which has been secured without the loss of time and expense that would be entailed by a topographical survey.

By the terms of the act making the appropriation the investigation was limited to the area to be covered and the problems to be studied and examined. The area designated by the act lies between the ninety-seventh meridian and the foot-hills of the Rocky Mountains. The problems to be studied are confined to artesian wells and their utility, and the extent and limit of the artesian basin within this area.

It was decided to keep strictly within the requirements of the act, but the agents and others were instructed to keep their eyes and ears open and to make notes (without expense or loss of time) of other sources of water supply. A large amount of information has, in this

Woonsocket Wells.

Six-inch stream 27 feet high.



Boring Machinery for Deep Wells.

way, been obtained and will appear in a supplemental report in which it is proposed to assemble the data collected concerning the existence and methods of utilizing other subterranean waters which are not artesian in their character.

One of the most important questions for the use of the geologists was No. 9 of the first circular on artesian wells;* yet the answers to that question were the most unsatisfactory of all the others. In a majority of cases the total depth was the only record kept of the well, and that was many times uncertain, as we have cause to believe from the conflicting statements, and the same remark will apply to the size of the casing towards the bottom of the wells. The pressure of the wells was generally observed by the agents and geologists by the aid of pressure gauges furnished by the Department. The pressure given is in pounds per square inch generally when the flow was shut off.

The flow of the larger wells was generally measured by passing the water over a weir. The flow of many of the smaller wells was estimated.

The investigation shows the existence of an artesian basin in the Dakotas, known as the James River Valley Basin, which is tapped by about one hundred and forty wells scattered over a territory four hundred miles or more in length from north to south, and from forty to fifty miles in width. In this area the present flowing wells in North and South Dakota are confined. Failures to find flowing water by rock-bored wells have occurred along the eastern line of this valley. This line, or the dividing line between the James River and the Red River of the North, probably marks the eastern boundary of this great basin. West of this line, in the Dakotas, borings for artesian waters have been successful when made deep enough to penetrate the water-bearing stratum—the Dakota sand rock. This sand rock, which underlies the James River Valley, is composed of a very soft, porous, whitish sand of unknown thickness. It has been penetrated 80 feet with a drill without reaching its lower bed. It is so soft that the drill penetrates it in many localities by its own weight. It lies from 600 to 1,800 feet below the surface of the country. The records of the wells show that this water-bearing rock dips to the north. On a line from Yankton, in the extreme southern part of South Dakota, to Devil's Lake, in the northern part of North Dakota—which is 15 degrees west from north—the dip is 830 feet, being about $2\frac{3}{10}$ feet per mile, while the surface dips in a contrary direction on an average of eight-tenths feet per mile. The pressure at the top of the wells ranges from 20 to 167 pounds per square inch. The area of greatest pressure in this basin, as has been determined from existing wells, lies in the central portion of South Dakota. The greatest pressure in the water-bearing stratum is near Jamestown, in Stutsman County. One of the problems to be solved in connection with this artesian basin is to determine, if possible, the location and true origin of its supply as well as the nature of the underground water course from its source to the valley of the James River. Surface indications and outcroppings suggest that the supply comes from the west. There is no gathering ground of sufficient extent or elevation in any other direction to produce the conditions that exist in this basin. The fact that the flow and pressure of the wells, that have been in constant activity for nearly five years, have not diminished, leads us to predict that a great many more wells can be put down in this basin without any serious reduction of pressure or flow.

* Circular No. 1, relating to artesian wells, will be found in Exhibit "A," following the report of the General Geologist.

I think I am safe in saying that the Dakota artesian basin is the largest and strongest yet discovered in the United States, or even in the whole world. There are some wells of very large diameter that discharge more water than some of the Dakota wells, but when the size of the bore is taken into account the Dakota wells not only yield a greater amount, but maintain a flow very nearly that which is due to the hydrostatic pressure less the resistance caused by the friction of the water through the pipe. Some artesian wells will show considerable pressure when they are closed, but discharge comparatively small quantities of water when allowed to flow freely. This indicates that the supply is not fully maintained, or, in other words, the water bearing stratum is of such a character as to impede the passage of the water freely through the rock. Nearly all of the Dakota wells throw out large quantities of sand with the water when allowed to discharge freely. Some of them have thrown out thousands of cubic yards of sand. This fact indicates what some of the drillers claim, that the water-bearing stratum is simply a loose sand. Another fact is shown that the water has quite a free movement through the sand and that when the wells have been discharging their full volume for days the pressure reaches its maximum almost the instant they are shut off.

Taking into account that from two to five years no diminution of the pressure has been noticed, that one well does not interfere with the flow of another, and that the supply seems to come almost as readily to the bottom of the wells as if they penetrated a body of nothing but water, I am led to believe this basin to be one that will furnish a very large amount of water without any serious diminution of pressure or flow.

There are indications of another important artesian basin in the vicinity of Waco, Tex. This basin was not thoroughly examined for want of time. This water-bearing stratum lies over 1,800 feet below the earth's surface and about 1,200 feet below the level of the sea. An 8-inch well at Waco, 1,834 feet in depth, has a flow of 833 gallons per minute with a pressure of $59\frac{3}{4}$ pounds per square inch when closed, the water having a temperature of 102 degrees.

Considering the theoretical flow due to a pressure of $59\frac{3}{4}$ pounds per square inch through 1,834 feet of 8 inch pipe, this well would indicate that its supply must come from a loose and porous rock. The quick response of the maximum pressure, when the well is closed, is another indication of an unobstructed flow of water through this water-bearing stratum. As yet we have no idea of the extent of this basin or of its source of supply. Further geological investigations and additional borings will be necessary to determine these matters. There are other artesian wells of more or less importance scattered here and there over a large part of the country examined, which will be noticed in the reports of the geologists. There are two other notable artesian basins lying in the drift formation in which artesian wells have been successful, one being in the valley of the eastern part of North and South Dakota. These wells are of small bore, and the water is used for domestic purposes. Wells of larger diameter would undoubtedly yield sufficient water for irrigation purposes, but as irrigation is not usually required, smaller wells only are put down for domestic and stock purposes.

The other basin is situated in the San Luis Valley in Colorado, the wells in which are of larger bore, and the water is used for irrigation. As this valley is considered beyond the western boundary of the territory to be investigated, no examination of it was ordered.

Professor Carpenter, the agent for Colorado, sent out several letters of inquiry and obtained considerable information regarding these wells It is reported that there are over 3,000 wells in this valley, and the

water from them is largely being used for irrigation. It is estimated that from 10,000 to 15,000 acres will be irrigated this season from this source. The wells are inexpensive ones to put down. Many of the farmers are putting down their own wells, the cash outlay being only for the casing. The farmers find that the water from these wells costs them less than to purchase it at the ordinary rates from the ditch companies.

The people living in the country lying on either side of the 100th meridian, of what is called the semi-arid country, have but little or no practical knowledge of the methods of utilizing the waters obtained from artesian wells and other sources for irrigation purposes, consequently little irrigation, comparatively, is done in this country and yet many parts of it have greatly needed it during the past two years, nearly as much so as any portion of the arid country.

The flow of water from the average Dakota well is small when compared with the carrying capacity of an ordinary irrigation canal, yet by the aid of storage reservoirs a well having a flow of 1,000 gallons per minute can be made to serve over 1,000 acres of land per annum. This estimate is based on the assumption that the water can be held in a reservoir when not being used for irrigation, and one-half of it may be lost by evaporation and percolation, and in transporting it to the field, also assuming that 9 inches in depth per annum will be required in addition to the rain-fall for the growing and maturing of crops.

The investigation shows that artesian wells of 6 inches in diameter and from 800 to 1200 feet deep, cost from $3,200 to $5,000—we will say $5,000 including reservoir—then we have $5 per acre as the first cost to provide for irrigation. The average cost for irrigation from canals in Colorado, is $3.20 per acre, the maximum sometimes being as high as $12 per acre. From these estimates it will be seen that the cost of water from this class of artesian wells is not excessive, especially when we take into consideration the increased value of land when brought under irrigation. Take Texas for an example: The average price of land with means of irrigation, according to the returns from several hundred inquiries, is $8.72 per acre. The estimated value of the same land is placed at $73.50 per acre provided it can be supplied with water for irrigation purposes. According to these estimates the average increased value of land, in the semi-arid portion of Texas, will be $64.78. This rate of increase will be less in the more northern portion of the country, but in no instance will it be less than $10 to $15 per acre, so that a wide margin is left to cover an excess in the cost of water per acre or a greater amount of what is necessary to serve an acre than is assumed in the above estimate.

Attempts to utilize the waters of artesian wells and other subterranean waters for irrigation purposes are not new or untried experiments. Millions of people have been for thousands of years, and are now, living in countries which have been, and would now be, barren deserts were it not for the utilization of these underground waters which have been brought to the surface by the aid of crude appliances. What has been done successfully by means of the crudest kind of machinery in other countries can be accomplished by the inventive genius of the American people. Nearly every acre of the country under consideration is susceptible of cultivation. This country comprises the great wheat region of the Northwest, the great corn belt in the central portion, and extends into the semi-tropical country of the South. It is a country of great resources, and its future possibilities can hardly be estimated. Some of it needs only a better distribution or a supplement to the annual rain-fall. It is quite probable that a portion of this coun-

try will, in due time, be served with a more equitable distribution of the rain-fall, as has been the case in the country adjoining it on the east, but there is no question of the needs of the people at the present time. Congress but recently made an appropriation for carrying on an irrigation survey to develop, for the benefit of the people, the country further west and near the mountains, but the benefits of that appropriation have not reached this people. They must receive their water supply from different sources, and the problems for obtaining this supply are very different from those adjacent to the mountain regions.

The following are some of the most important things brought to notice during this investigation:

(1) The existence of a large artesian basin in the Dakotas which is indicated by the number of flowing wells scattered over an area of about 12,000 square miles.

(2) The presence of an abundant supply of water in a loose sand stratum of great thickness and subjected to great pressure, which is fully maintained after being pierced by numerous wells flowing their full capacity for years.

(3) The probability of an extension of this basin to westward or a considerable distance from the James River Valley developments and having similar characteristics.

(4) The probable existence of an artesian basin in Texas similar to that in the Dakotas, and of unknown area, but lying at a greater depth from the surface.

(5) The existence of several artesian basins in other parts of the country examined, which have similar flows, from which water is obtained in sufficient quantities for domestic use, and, in some instances, for the irrigation of small areas.

(6) The existence of two artesian basins lying in the drift where flowing water for domestic use and for irrigation is obtained at a very low cost.

(7) The necessity of irrigation to prevent total loss of crops, at times, and for their full development nearly every year.

(8) The existence of large supplies of subterranean waters underlying quite generally the whole territory examined.

(9) The lack of knowledge of the majority of the people of the methods for utilizing the artesian well and underground waters for irrigation purposes.

(10) The need of a closer and more extended geological examination to designate, as near as possible, where it is probable that water may or may not be obtained.

(11) The necessity of verifying by test experimental work some of the conclusions of the geologists.

(12) The necessity of investigating the subject of utilizing the subterranean waters and the extent of country which can be reclaimed by them and to report on methods for bringing such waters to the surface and the cost therefor.

It is unnecessary for me to go into details of the information gained by means of this investigation.

The several reports of the agents and geologists will, I trust, furnish you with these.

Had the time for organizing and carrying on this investigation been even a few days longer, the information gathered and the work performed would have been greatly increased.

EDWIN S. NETTLETON,
Supervising Engineer.

The HONORABLE SECRETARY OF AGRICULTURE.

Huron Well.

Huron (South Dakota) Well, showing Discharge through Six-inch Pipe.

REPORT OF PROF. ROBERT HAY, F. G. S. A., GENERAL FIELD GEOLOGIST OF THE ARTESIAN WELLS INVESTIGATION.

In the short time allowed to this preliminary investigation the relation of artesian wells to irrigation, in the region from the ninety-seventh meridian, to the foot-hills of the Rocky Mountains has been examined by seeking answers to the following questions:

(1) In the region under examination are there any artesian wells now used for irrigation?

(2) If so, are the wells so used in groups or isolated?

(3) Are any of the wells available for irrigation to a larger extent than at present?

(4) Can the areas in which existing wells are found be defined and their geologic conditions determined?

(5) Are there other areas whose conditions are similar where artesian water may probably or possibly be found?

(6) May the areas already known be expected to yield more water with further exploration?

(7) In what way are the phenomena of springs and the subflow of river valleys related to the conditions of artesian wells, and are the springs and subflows available for irrigation?

The first three of these questions are answered very briefly, and may be disposed of in a single sentence. There are many groups of artesian wells in the region examined whose waters are largely available for irrigation, being, to some extent, now so used and capable of considerable development in that direction.

These groups may be described geographically as follows:

(1) The wells of the Red River Valley in northeastern North Dakota.

(2) The wells of the James River Valley in the two Dakotas (North and South).

(3) The wells of the Yellowstone Valley at Miles City, Mont.

(4) The shallow wells in the drift formation on the eastern side of the two Dakotas.

(5) The wells of northern Nebraska.

(6) Four groups of wells in southwestern Kansas.

(7) The wells of the La Pondre, Denver, and Pueblo basins in Colorado.

(8) The Fort Worth and Waco groups in Texas.

(9) The wells of New Mexico.

(10) The wells of Wyoming.

No. 9 represents attempts, rather than successful artesian wells. One really flowing well at Las Vegas was closed off because the boring was wanted for other purposes. One at Santa Fé did not quite rise to the surface.

The others are all groups of flowing wells. The aggregate number of wells is about one thousand four hundred. Some have flowed undiminished for years, but from various causes between three and four hundred now only yield water to the pump. This is notably the case at Fort Worth and Denver, where the cause of the failure to flow is the great number of wells in a limited area. This fact points to the necessity of local legislation in the districts where artesian water is abundant to prevent the too great propinquity of wells whose water is expected to be used for irrigation.

The writer has seen some of the wells in every group mentioned above, except No. 10, has tested the pressure of some of the largest, and measured the flow of many, both large and small. He has examined the drill record of some of the wells in nearly all the regions named, and has been able to come in many cases to definite conclusions as to the source of the waters and the other geologic conditions, and also to notice the relation that these have to the springs and water-courses of the different districts.

It will be proper here to state that though the writer has visited the several districts referred to above, yet he only gives as his own the statement of facts and conclusions that relate to western Kansas and neighboring parts of Colorado and Nebraska, and a small district in Montana. It is a pleasure to say that he has had coadjutors in the geologists of the several States, with whom he has been proud to work and on whose ability he relies for the expression of the facts in the several districts to which they have devoted their attention. The reports of Prof. P. H. Van Diest, for Colorado and New Mexico; Prof. L. E. Hicks, for Nebraska; Prof. G. E. Culver, for the two Dakotas east of the Missouri River, and Prof. G. E. Bailey, for the Black Hills region of South Dakota and adjoining parts of Wyoming, and the detailed information they contain, with the illustrative diagrams and maps, must be taken as the basis of this mere generalized statement for their respective regions. These reports are hereto appended, and respectfully commended to your attention.

Without further specific reference to the queries that remain to be answered we may now discuss the facts on which their answer depends.

The most important, perhaps, of the groups of artesian wells previously enumerated is that of the James River Valley of the two Dakotas. This group stands first because of—

(*a*) Its large area and present large number of wells—nearly 20,000 square miles, and about one hundred and fifty wells.

(*b*) The great pressure and copious flow of all the wells already bored—pressures from 60 to 153 pounds to the square inch, and many flows over 1,000 gallons per minute and one nearly 3,000.

(*c*) The immediate availability of many of them for irrigation, some being now so used.

(*d*) The probable large increase in the number of the wells without diminution of the flow.

The James River Valley, though somewhat closely corresponding with the present known limits of this artesian district, is not connected with it in the direct way of cause, and probably does not limit the area of the real artesian trough, which is a deeply seated synclinal fold, whose axis is approximately north and south, and whose eastern edge is hidden in eastern Dakota by later accumulations of the drift period, and whose western rim is upturned on the eastern flanks of the Black Hills and the more distant mountains of the Upper Missouri.

The water-bearing rock, from which the fountains burst with such

force when their cover is penetrated by the drill in the James River district, is a loose sandstone, or series of sandstones, belonging to the lower Cretaceous period, and known as the Dakota group. The outcrop on the sides of the western mountains is several thousand feet higher than in middle Dakota, and receiving there considerable rain-fall, the sandstones pass the water through their porous substance, and as they proceed east they are covered to a thickness of over 1,000 feet—in places 2,000—with shales and other later cretaceous beds, more or less impervious, and which hold the water down in the Dakota sandstones. Professor Culver believes that he makes out, from the records of the wells which he has studied, that these impervious beds overlap the pervious sandstones to the east, and thus seal in the waters at the low eastern edge of the artesian trough, and so prevent their escape. On the southeast boundary of the region this overlap does not take place. The sandstones are exposed by the erosion of the upper beds, and the waters do escape in springs on the Iowa frontier, and the pressure in the wells at Yankton and Vermillion is much less than farther up the James.

The source of supply of the waters being so far west, and at such an altitude as the western mountains, and the intervening space so well covered by impervious beds, it would appear that artesian water should be had from the same Dakota sandstones much farther to the west and northwest than has yet been tested. On the other hand, the thickness of the later deposits in that region is such that it will be costly to reach the main water-bearing rock. Professor Bailey, however, points out that in part of the Great Sioux Reservation that is open to settlement the erosion along the valleys has been so much that the Dakota sandstones may be reached probably at less depths than in the northern part of the James Valley. This may also be true in valleys north and west of Bismarck, into Montana.

It should be noted that existing wells have their water highly mineralized. The deepest most so, but not uniformly in the order of their depth. None so far are mineralized to the extent that they would injure vegetation.

Before leaving the consideration of this group of wells it should be remarked that the outcrop of the Dakota formations on the western mountain slopes is succeeded westerly by the outcrop of rocks of a much less pervious character—the Jura-Triass—from whose surface the waters run off largely to the exposed Dakota sandstones, which are also underlain by the same Jura-Triass, which helps them to retain the water and convey it eastward. How far east these Juro-Triassic rocks extend is not known, but they do not seem to be present at the eastern boundary of the district, but apparently their place is taken by metamorphosed beds whose hardness and texture give the same quality of impermeability. Drillers call them granite, but it is not probable that real granite is here except in limited areas.

It is interesting to note that on the western side of the Black Hills, in Wyoming, the Dakota sandstones yield flowing wells of salt water, with a considerable amount of oil, and that natural gas is also present.

In southwest Kansas, and just over the line in Colorado, in the Arkansas Valley, there is a group of artesian wells which, at a depth of less than 300 feet, derive their waters from the Dakota sandstones. These sandstones outcrop in middle Kansas and eastern Nebraska along a line running from east of north to west of south, and give evidence of their water-bearing capacity, but there are reasons for believing that they do not get their supply in these States from the exposure in the

foot-hills of the Rocky Mountains. One reason is that, in that part of the foot-hills corresponding in latitude with southern Nebraska and part of Kansas, the Dakota sandstones in their western exposure, are, to some extent, themselves metamorphosed into quartzite and lose their permeable quality, thus hindering them from absorbing as much of the rain-fall as they otherwise would. Another reason is found in the fact that the wells referred to in Kansas (near Coolidge) do not have sufficient pressure to lift the waters more than 20 or 30 feet, and neighboring high prairie is 200 feet above them. The source of these wells is probably in local breaks in superincumbent strata not far to the west, or even in outcrops which occur some miles south.

A well at Syracuse, 16 miles east of Coolidge, penetrated the same beds but did not obtain water that came to the surface, though it rose considerably in the tube. It is the opinion of Professor Hicks and Professor Bailey that northern Nebraska may really have an extension of artesian conditions from southern Dakota and be part of the James River district. This is probable, as the source of the waters would be the southeast flank of the Black Hills where metamorphism of the Dakota formations does not exist. For the rest of Nebraska, with western Kansas and part of Colorado, it is only to be expected that artesian waters will be found coming from the Dakota sandstones in limited areas where the local conditions may be as favorable as at Coolidge. Such areas will probably be found in the region indicated, but the Government experiments made nine years ago at Cheyenne Wells and Akron, do not encourage this view, but a second well recently sunk at Richfield, in Morton County, with a moderate flow seems to be in the Dakota formation. It is not as deep as another well at that place.

In the eastern part of both Dakotas there are a number of wells of much less depth than those described above which we have given as group No. 4. They obtain their water in gravels and sands in what is known as the Glacial Drift, a sheet of which, from 15 or 20 to 200 feet thick, overspreads the Dakotas east of the Missouri and stretches into Iowa and all over several other States. Where the gravels are covered by beds of clay, as is very frequently the case, the piercing of the clays by the drill allows a flow of artesian water, not very strong, but locally abundant and of good quality. It is less mineralized and cooler than the water of the deep wells. The wells may be multiplied and utilized to a much greater extent than at present.

The rivers issuing from the mountains to the plains—the Platte, the Fountain, and the Arkansas—are all used for irrigation, but the districts through which they flow outside the foot-hills are also supplied with artesian waters. The geologic structure of at least a part of this region is well understood, and the wells, of which there are over three hundred, in and around the city of Denver, are said to be in the Denver Basin. The section of this basin given in the report of Professor Van Diest will repay study. It represents what may be called the ideal conditions for obtaining artesian water, though a section made in a direction at right angles to this would show that the ideal conditions do not exist all round. This section shows that these wells receive their water from formations much newer than the Dakota sandstones.

They are in beds of Tertiary age, only a few reaching down into the highest Cretaceous or transition beds known as the Laramie formations. There is abundance of water derived from the upturned exposure of these beds on the flanks of the mountains. But the multiplication of wells in the city of Denver, where any man bores where it pleaseth him, has reduced the head of water so that very few of the wells are now

flowing wells; but the pumps which have succeeded the natural flow have given no indication of reduction in the quantity of water. Some wells outside the city are used on a small scale for irrigating, and others for dairy purposes on farms irrigated by the waters of the Platte. For the details of the other basins having wells Professor Van Diest's and the field agents' reports must be referred to.

In New Mexico, at Santa Fé, at Las Cruces, and other places there are stratified beds upturned in the foot-hills of the mountains, which suggests the possibility of other basins as complete as those at Denver or Pueblo. Near Santa Fé, in a boring already made, the water rose considerably, but not to the surface. It is possible that another location, not very far away, would give better results. But the whole region needs further investigation.

There is a group of wells yielding a considerable amount of water at Fort Worth, Tex., but the same thing has occurred as at Denver. There are too many in the area, and the force of the water has diminished, so that only three or four out of two hundred and forty are now flowing. At Waco is another group of strong wells. These are comparable with the Dakota wells, one having a flow of nearly 1,000 gallons per minute and a pressure of sixty pounds per square inch. The records of the drilling of these wells and the surroundings have not been sufficiently studied to indicate precisely the geologic age of the water-bearing beds and their probable continuity beyond the limited arears now proved, and this is one of the things to be observed if this investigation is continued.

In southwestern Kansas there is a group of artesian wells in the upper valley of Crooked Creek, northeast from Meade Centre. There are about eighty wells with flows varying from 2 to 3 gallons per minute to between 60 and 70 gallons.

Every farm has one; some farms have several. The writer, who has been in the district twice since they began to be bored, has seen twenty, and measured the flow of eight. Mr. B. F. Cox has two wells, and was the first to find artesian water. His place is NE. ¼ of Sec. 5, T. 31, R. 27 W. One well is 175 feet deep, the other 142 feet. They seem to flow about equal quantities. The measure of both in a united channel at some distance from the wells gave 18 gallons per minute. Mr. Cox irrigates with this about 4 acres of land, and besides supplies a large carp pond. He says, with care it would be sufficient for the irrigation of 10 acres. Other wells are on contiguous farms. The following is a list of those whose flow was measured:

Name of owner.	Depth.	Flow per minute.
	Feet.	*Gallons.*
George Edwards	155	36
Do	165	32.4
Do	185	29.6
I. A. Marts	140	66.6
I. P. Bowers	125	37.3
Oliver Norman	127	37.3
B. F. Cox	175	18
Do	142	

The well of Mr. Marts is the largest in the district, but there are quite a number not here given that have a flow between those of Cox and Norman, and there are a larger number still that flow from 6 gallons down to 1 gallon per minute. Mr. Cox's wells are almost the furthest up the valley, and are well up on the side of the hills. Those that are lower—as Messrs. Bowers and Norman—have a flow that would rise from 15 to 20 feet above the surface. None are so strong as to rise to the level of the neighboring high prairie. The wells at lower levels than those in the table are of less depth, the smallest depths being about 50 or 60 feet. The water from all these wells is clear and soft, and some of the stronger ones bring up a little coarse sand that shows their origin. Many of the wells are used for irrigation, but none to its full ca-

pacity, and most of the water runs to waste after filling cattle-troughs and pools. Mr. Norman, as well as Mr. Cox, has a carp pond, and the fish thrive wonderfully.

Just lower than the lowest wells of the district is or rather was a strong spring coming out below a clay bank 10 or 15 feet high. It brought up a fine sand which when stirred up with a pole emits a peculiar sound somewhat like that heard when bending the so-called flexible standstone. With the exception of a very small one several miles away, there are no artesian wells lower down the valley of Crooked Creek than this spring. The spring has less flow or is choked up since the wells have been bored.

The subsoil in all the region of the wells is a peculiar soft, bluish, putty like clay, or gumbo. It is not the best of soil for irrigating, but as it reaches down to the sand and gravel containing the water, it is a prime cause of the artesian flows. It is a thoroughly impervious covering, which when broken by the drill permits immediate outburst of the confined subterranean water. The sand or gravel in which the water is obtained is manifestly a broken-up form of the Tertiary grit and the source of the water is not far to see, as the grit outcrops on the edge of the high prairie for some miles, and can absorb all the rain-fall.

The wells of this region have thus been described and their water traced to its source, not because of the areal importance or the quantity of the flow, but because of the origin in the Tertiary grit, and the fact that the description given was written a year ago and there is no diminution of their flow and the wells have been increased in number.

In the same county, farther to the southwest, is a creek whose waters have perennial flow, being supplied from springs which issue from the same Tertiary grit. A portion of the waters of this creek is being used to irrigate 400 acres of land, and if all were used 1,000 acres could be served. I have thus described the Tertiary grit:

The term grit is descriptive of this formation everywhere, yet it is of varying constitution. In places it incloses a fine powder, but the powder is largely siliceous, is useful as a polishing powder, and appears to be volcanic in its origin—wind-blown volcanic glass from the Tertiary centers of eruption in the west. Elsewhere the grit is an aggregation of sand and lime, which we call its mortar-like form. Again the lime exceeds the sand in quantity, and it is sufficiently fine to be used for inside plastering. Then we have the mortar form, inclosing abundant pebbles, quartz, feldspar, diorite, greenstone (hornblende), and more rarely granite with other igneous rocks. Then the limy matrix almost disappears, and we have a heavy conglomerate of water-worn pebbles of the rocks above mentioned, with jasper, quartzite, and agate from the size of a nut to that of a large apple. Sometlmes also there is a bone or a piece of completely silicified wood. The mortar-like form often hardens into a building stone, and its softer beds contain hard, tough nodules like indurated—not silicified—chalk. The conglomerate form changes at times into beds of a fair quality of sandstone. In some places it shows as a hardened bed of gravel, with well-marked cross-bedding. The mortar like form is often a fossil bed, yielding bones of mastodon, *Aphelops*, and turtle. There are in many places root-like concretions penetrating the softer forms of the grit, and where these softer forms are of considerable thickness—they attain in places a depth of 15 to 20 feet—they are characterized by harder ledges at intervals of from 2 to 3 feet, which give very bold forms in weathering. The conglomerate is also manifested in abrupt breaks and rocky ledges.

In the Arkansas Valley the conglomerate of the grit is mainly composed of pebbles of dark red feldspar. This is so marked a feature that its exposures, covered with the loose pebbles, can be recognized at long distances by their ruddy glow in the sun. In the valley of the Cimarron and in counties farther east the conglomerate is more often composed of quartz pebbles and pale feldspar, giving a whitish or grayish tint to the exposures. In several well-marked instances I found the mortar form and the conglomerate together, indicating that they are not, as I had at first supposed, local variations of synchronous deposits. I found the mortar form below the conglomerate, the former having in those places its usual scant supply of pebbles. Rocky Point, a bold ledge of the conglomerate 5 miles west of Dodge City, gave this juxtaposition of the two forms, the mortar form showing only on the eastern or lower slope of the point, and disappearing under the conglomerate. Elsewhere I found the mortar form embedding not only the pebbles of igneous rock, but also pebbles, both water-worn and angular, of the Cretaceous rocks of the region, these fragments being more or less silicified. A small patch of white sandstone, of which there were several near in Harper County (Sec. 5, T. 32, R. 5 west), had similar relation to the underlying red rock (Jura-Trias). The red rock, a nodular clay, shades upward into the sandstone, the intermediate part being a conglomerate of quartz pebbles in a pasty

matrix of the red rock material. The sandstone itself has some pebbles of smaller size, and in the conglomerate the larger pebbles are below, and the least amount of the coloring matter—the pasty matrix—above. At another, "Rocky Point," on the Cimarron, in Morton County, the grit lies on the Dakota sandstones, and great erosions of previous epochs are well illustrated by the difference of the formations on which the grit rests.

This description of the Tertiary grit is that of a formation by no means confined to Kansas. While it is found in at least 20,000 square miles of that State, it is also conspicuous in an equal area of eastern Colorado, a larger area of western Nebraska, and in similar areas of New Mexico and Texas. Its character for holding water is continuous through all that region. On the level prairie it is covered up by what we have called Tertiary marl, a loess-like deposit not altogether impervious to water, but so much so in most of its area to hold down the accumulated waters in the grit. The marl varies from 20 or 30 to 200 feet in thickness, and the grit from 20 to 100. Through all this region the high prairie wells are sunk through the marl and find abundance of water in the grit. Neither steam nor wind pumps reduce their supply. The conditions in Meade County, Kans., which result in an artesian supply of water, are strictly local, but it is quite possible, even probable, that there may be many repetitions of these local conditions in this vast region.

Further, all the numerous springs of the region are from this grit, and many of them may be tapped above their present outlet and their waters made available for extensive irrigation. All the rivers of the plains, as distinguished from those whose sources are in the mountains, have their origin in the superabounding waters of the Tertiary grit. This is true of the Republican, the Arickaree, the Smoky, the Solomon, the Prairie Dog, the Saline, the Cimarron, and numerous others, whose beds are merely storm-used arroyos till they have cut below the grit, and then their channels have perennial streams, except where hidden in sand, which is largely the débris of the grit. In Wallace County, Kans., the first permanent water of the Smoky, just below the embouchure of such a spring-fed affluent, has been used for irrigation since 1873. Professor Hicks regards the development of the water in this Tertiary formation as a controlling factor in the development of the resources of western Nebraska. Professor Bailey suggests similar conditions in Wyoming. And this is largely true from the Pecos to the Platte.

The methods of this development will be various. The water of springs and rivers may be raised high enough for useful amounts of irrigation by various forms of water-lifts, horse-power, and the wind-pump. The last of these will certainly play an important part, and the people should be made acquainted with its best form. Urban communities, even small ones, in parts of the region not far from coal, will find it cheap to use steam to raise this water. This is already exemplified at some of the railway towns in eastern Colorado.

There are other artesian wells in Kansas. One at Larned has the largest flow in the State, nearly 300 gallons per minute. It is not available for irrigation because of its highly mineralized condition, which, however, gives the water a medical value, which is being utilized. A similar well at Great Bend has a flow of about 400 gallons per hour. There is a still smaller one near the Colorado line, in Morton County, which would be available for irrigation, only that its flow is slightly less than that at Great Bend.

These wells all have their water in the Triassic strata or "red beds." There are strong reasons for believing that the flow at Richfield, Mor-

ton County, is not due to the hydrostatic pressure to which we attribute the usual flow of artesian wells. It may also be so at Great Bend, but the great flow at Larned must have the usual cause of artesian supply, but where the supply of water is to be found is not certain. It is possible that its position in the bottom of the synclinal trough of the formations may have to do with it, and it is not improbable that the water may find its way from the surface through cracks and fissures in the strata beneath some of the remarkable drainage areas to the west, which have no visible outlet.

A group of from 20 to 30 wells, of flow varying from 1 or 2 to 15 and 20 gallons per minute, at Miles City, in the Yellowstone Valley, in Montana, deserves brief notice. They are useful for irrigation of gardens and lawns, for domestic purposes, and watering cattle. The water is obtained from close sandy beds of the Laramie formation. Their existence warrants the belief that others may be found in the large region where the Laramie is developed to a great thickness, and the uplift of the strata towards the mountains would suggest, with the close-grained character of the beds, that the supply may be perpetual.

The observed facts then show that there are artesian wells in the subarid region investigated in formations of very different geologic age. In descending order they are:

The Glacial Drift.
The Tertiary formations.
The Laramie.
The Dakota sandstone.
The Triassic "red beds."

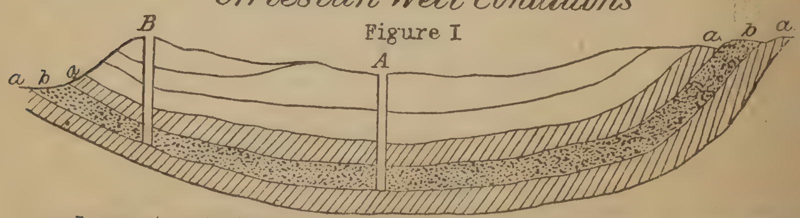
The diagram (Fig. I) is easily understood by the legend. It represents at A the ideal conditions of an artesian well.

Fig. II shows how at A 2 a failure to flow would be caused by a breach of continuity of the lower impervious stratum.

The form of breach of continuity may be very different from that suggested by the diagram. It may be in the form of change of texture. For example, a bed of clay shale may gradually pass into a bed of sandy shale and from that to sandstone—that would be a virtual continuation downwards of the water-bearing stratum downwards—and so the water might be diffused to great depths. Again a breach of continuity may occur in the water-bearing stratum itself, sandstone may become sandy shale and pass into clay shale, and so stop horizontal distribution of the water. Again the breach of continuity may occur in the upper impervious layer, when great diffusion of water will take place in the

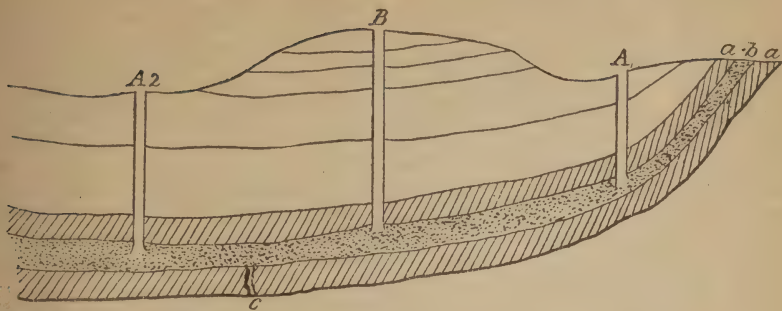
Diagrams,
Artesian Well Conditions

Figure I



a a. Impervious beds dipping towards center of Basin, inclosing porous bed (b)
A. Well near center of basin with Artesian Flow
B. Well on higher ground without Artesian flow, because located higher than outcrop of b.

Figure II.

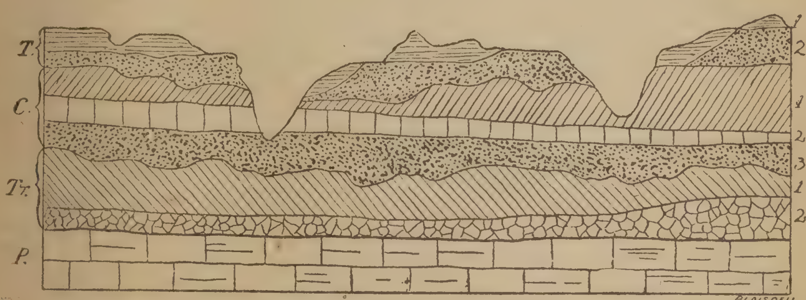


A.B. a.b. As in Fig 1.

c. Breach in the continuity of the lower (a) impervious bed, causing failure of flow of A 2.

Figure III.

Representing foundations of Western Kansas and parts of Colorado and Nebraska.



T. Tertiary. 1 Pliocene marl. 2. Miocene grit.
C. Cretaceous 1 Niobrara. 2. Benton. 3. Dakota.
Tr. Trias. 1 Red beds. 2. Saliferous horizon.
P. Permo-carboniferous.

surface strata. There will be an abundant supply in wells but no pressure. Lack of continuity of rightly conditioned strata may, therefore, cause failure of artesian supply when there is nothing in sight to suggest failure, and it may be perfectly impossible to locate the cause.

Fig. III represents in western Kansas, and neighboring parts of Colorado and Nebraska, the probable arrangement of the strata. It shows also the way in which the valleys have cut into the formations. The Tertiary (miocene) grit is seen of irregular thickness, and is occasionally missing. Where it is exposed on the slopes of valleys it has springs as previously described. The direction of the section is north and south and so does not show the dip, to which it is nearly transverse.

It is just possible that the permo-carboniferous does not underlie southeast Colorado, nor the Trias underlie Nebraska, but the higher beds seem to underlie all the plains region, and farther northwest some higher cretaceous beds are found also beneath the Tertiaries.

The Tertiary marl is the smooth covering of the plains region. It shades off into the deposit known in eastern Nebraska and Iowa as Loess, but in southern Kansas it is very distinct from that formation. It everywhere holds down the waters of the Tertiary grit and shading down into it the water is often said to be in the bottom of the marl.

With these diagrams, and those of the several geologists, it is believed that the artesian problem and that of the water supply of the plains generally may be understood.

From the foregoing statements it will be seen that—

It is quite possible, and in some of the cases highly probable, that known artesian areas will be greatly extended by further exploitation.

It is certain that some of the areas as already defined may have many more wells than now exist without reducing the supply of water.

The diminished supply, or rather the loss of force to the extent of wells ceasing to flow, at Fort Worth, in Texas, and at Denver, Colo., is a warning that should operate to prevent the clustering of wells too closely together, even where there is an ample supply of water.

The phenomena of springs, which may be defined as natural artesian wells, form a necessary part of the things to be examined in such an investigation as the present, as they suggest limits within which artificial artesian wells can scarcely be expected, besides the fact that such examination of springs may lead to their utilization in irrigation.

The sandy nature of formations which in a large part of the plains region are noted for their water-bearing capacity is the main cause of the conditions which allow some of the river valleys to have a subflow of water equal to or perhaps greater than that of the visible streams. The conditions of hydrostatic pressure under which the subflows exist suggest that their phenomena are directly related to those of artesian wells and springs, and may properly be investigated with them.

In this report but scant attention has been given to New Mexico and little to Texas. The circumstances of the investigation have made it scarcely possible to do otherwise. The report of Professor Dumble, which, as State geologist of Texas, he made directly to the Secretary, on what may be called the artesian geology of his State, though brief and not expounding the phenomena of the known artesian areas, shows that there is high probability of considerable extension or repetition of those areas, and the reports of the able field agent, Mr. Roesler, give a mass of material and summing up in connection therewith which will much simplify future investigation. In New Mexico the possibilities made known may become probabilities under further research, and in both this Territory and Texas comparatively small supplies of water will go far in the raising of the semi-tropical products of the region.

There is an important scientific question which, when answered, will have a great economic value, upon which some of the data acquired in this investigation will have direct bearing. It is, what is the rate of percolation of waters through subterranean rocks at various depths and of different petrographic texture? In the large area of the James River district the deep seated Dakota sandstones form a supersaturated bed which is an actual reservoir situated a great distance from its source of supply. A large number of wells will have to be running a great many years before the reservoir will be so lowered as to produce any phenomena that will indicate in any way the velocity from the outcrop to the well. But in the Denver basin a large number of wells have been running for such a length of time as to reduce the head of water, and the nearness of the outcrop of the water-bearing rocks of the basin is such as to supply some evidence as to the rate of percolation.

The excellent report of Professor Carpenter gives the records of the variations of two intermittent wells at Denver whose variability seems directly traceable to variations in rain and snow fall of the neighboring mountains. Observations on the subject have recently been collated in England, but the results obtained are yet only distant approximations to verities which, when accurately known, will be of great value. It is pointed out in another report that irrigation from artesian wells or other subterranean waters will always possess a value, due to the distance from the outcrop and slowness of the percolation, which does not attach to irrigation from surface waters. It is this, that it is not likely to fail in a dry season, as the effects of the dry season will probably not be felt on the wells for one or two seasons thereafter. It is probable that in wells very distant from the outcrop of the water-bearing strata there will never be any variation due to seasonal variation of rainfall, as the character of the percolation may establish a constant instead of variable outflow, even as the flow of blood in the veins of the body is a steady stream notwithstanding that that of the arteries is a movement of pulsations.

Besides the geologists the writer has been personally associated with all the field agents, and has received from them valuable assistance, and in travels of about 13,000 miles he was closely associated in more than half the journey with Col. E. S. Nettleton, the supervising engineer, to whose ability and kindly co-operation the success of the work is largely due. The arduousness of the work in the field was so incessant as to frequently strain the physical ability to perform it, but the encouragement received from time to time from the Department at Washington, through the special agent in charge (Mr. R. J. Hinton), was such as to stimulate to the use of my best efforts, which were given throughout the whole period.

The work done, it is hoped, will meet with your approbation, and in that hope this report is respectfully submitted.

EXHIBIT A.

U. S. DEPARTMENT OF AGRICULTURE,
ARTESIAN WELL INVESTIGATION,
Washington, D. C., April 21, 1890.

Mr. —— ——,
—— ——:

ARTESIAN WELLS.

1. Name of well, ——.
2. P. O. address of owner, ——, County ——, State of ——.

DEAR SIR: Pursuant to an act of Congress approved April 4, 1890, which requires the Department of Agriculture to make certain preliminary investigations concerning the character and location of artesian wells within the area embraced between the 97th meridian west longitude and the foot-hills of the Rocky Mountains, you are respectfully requested to fill out this blank with as full and accurate information as you can command, and return the same as soon as you can conveniently to the division field agent in the addressed envelope herewith inclosed.

Very truly,

RICHARD J. HINTON,
Special Agent in Charge.

3. Location of well: Section ——, town ——, range ——.
4. Well was begun ——, 18—, and finished ——, 18—.
5. What is the elevation of the top of well above sea level? ——. If unknown, give the distance above or below the railroad track at the nearest station, designating the railroad and the name of the station.
6. What is the total depth of well?
7. What is the total cost of the well including the tubing and casing?
8. What was the price paid per foot for different diameters of bores and for different depths?
9. What was the depth, thickness, character, etc., of the strata penetrated?
10. What is the flow of the well in gallons per minute when discharging freely or with any contraction of the orifice? (If the well failed to flow, give all particulars regarding the bore, and state cause for failure to flow if that is known.)
11. What is the pressure, in pounds, per square inch, of the water at the top of the well when the flow is completely shut off?
12. What is the pressure, per square inch, when the well is flowing —— gallons per minute?
13. Has the discharge increased or diminished since the well was first cased in its present position; if so, how much?
14. Has any sand or other solid matter been brought up with the flowing water? If so, what was its character and amount?
15. Has the water from the well been analyzed; if so, give the analysis or state where it can be obtained?
16. For what purpose is the water of this well used?
17. If used for irrigation, state the amount of land irrigated and its effect on grown vegetation?
18. Is the well so situated that the water flowing from it can be stored during the non-irrigation season?
19. What is the estimated number of acres that the water flowing from the well can be made to serve, taking account of what will be lost by evaporation and percolation?
20. What is the annual rainfall in the vicinity of the well?
21. What is the amount of rainfall during the cropping season, say from April 1 to September 1?
22. Is irrigation necessary for a full development and the maturing of crops every year? If not, what proportion of the years is it necessary?
23. What is the value of the farming land in your vicinity?
24. What would be the value of the land if it were provided with means for irrigation?
25. What would be a fair price, per acre, for the annual rental of irrigation water for common agricultural purposes?
26. What would be a fair price for water in perpetuity per acre?

[Enter in consecutive order in the proper columns, in the blank below. For a guide as to the form of tabulating the record of the well, see specimen record below.]

Character of strata.	Thickness of each foot.	Depth.	Remarks.

GENERAL REMARKS.

....

....

....

Character of strata.	Thickness of each stratum.	Depth from surface.	Remarks.
	Feet.	*Feet.*	
1. Black alluvial soil	2	2	Drove pipe to bed rock 10 diameter.
2. Impervious yellow clay	5	7	Struck surface at 14 feet.
3. Coarse gravel	7	14	
4. Fine sand and gravel	30	44	Top of bed rock. Bore 10-inch diameter.
5. Blue slate	65	109	Very soft.
6. Whitish sandstone	9	118	Small supply of water.
7. Blue limestone	35	153	At 175 reduced bore to 8 inches.
8. Black slate	205	358	Mud vein 352 feet.
9. Sandstone	16	374	Struck water at 360 feet.
10. Limestone	28	402	
11. Black slate	135	537	
12. Sand and quartz	2	539	At 538 reduced bore to 6 inches.
13. Sand red	102	641	Very dark red.
14. Blue slate	168	809	
15. Coarse sand and gravel	14	823	At 810 struck strong flow fresh water.
16. Black slate	5	828	

GENERAL REMARKS.

The well was tested at the 360 feet supply, but flow was only 6 gallons per minute and no pressure.

The well is now cased at 825 feet and flows 325 gallons per minute. At first, considerable fine sand came up with water.

Water is soft and very clear.

U. S. DEPARTMENT OF AGRICULTURE.

ARTESIAN WELL INVESTIGATION.

ARTESIAN WELLS.

[To accompany the general circular.]

Location of boring.—Names of persons who can probably furnish information:

1. Sec. —— T. —— R. ——.
   Name, ———, ———.
   P. O. address, ———; County, ———; State, ———.
2. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———: State, ———.

3. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
4. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
5. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O address, ———; County, ———; State, ———.

[Please give the same information regarding all important springs or other subterranean water flowing to the surface.]

Location—character—names of persons who can probably furnish information.

1. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
2. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
3. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
4. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
5. Sec. —— T. —— R. ——.
   Name, ——— ———.
   P. O. address, ———; County, ———; State, ———.
   State character, volume, and such other details as are obtainable of the said water supplies.

Give your own name ——— ———.
Post office ——— ———.
County ——— ———.
State ——— ———.
Return this and other blanks inclosed to ———.

——— ———,
Division Field Agent.

U. S. Department of Agriculture,
Artesian Wells Investigation,
Washington, D. C.

To ——— ———,
——— ———.

Dear Sir: Under an act entitled "An act to provide for certain most urgent deficiencies," etc., approved April 4, 1890, the following investigation had been ordered:

"To authorize the Secretary of Agriculture to make such preliminary investigations of an engineering and other character as will, so far as practicable, determine the proper location for artesian wells for irrigation purposes within the area west of the ninety-seventh meridian and east of the foot hills of the Rocky Mountains, twenty thousand dollars; and a report of all operations and expenditures hereunder shall be made to Congress immediately after July first, eighteen hundred and ninety:

"*Provided,* That no part of said amount shall be expended in sinking wells or the construction of irrigation works, and the work done under this appropriation shall be completed and a report of the same made within the appropriation, and nothing herein shall commit the Government to any plan of irrigation or the construction of works therefor."

In furtherance of the investigation thus ordered, you are respectfully asked to aid by replying as early as possible to the questions accompanying this letter. Please give also on the inclosed form the exact location (by section, township, and range, when possible) of all borings for water in your vicinity, and of all others known to you within the territory embraced by the ninety-seventh meridian of west longitude and the foot hills of the Rocky Mountains. State also whether water was obtained or not by the borings reported. The Department will be obliged by the receipt of

the names and post-office addresses of other intelligent and trustworthy persons who may, in your opinion, be able to furnish similar detailed information. This blank will be inclosed with return envelope, both of which will be mailed to you by the field agent for your division, to whom returns are to be sent.

Respectfully,

——— ———,
Special Agent in charge of Investigation.

U. S. DEPARTMENT OF AGRICULTURE,
ARTESIAN WELL INVESTIGATION,
Washington, D. C., April 21, 1890.

DEAR SIR: You are requested to furnish to this Department such information as you may possess, concerning all important springs and other subterranean waters flowing to the surface in your vicinity or of which you have knowledge. These to be located between meridian 97° of longitude west from Greenwich and the foot hills of the Rocky Mountains. Such waters coming from subterranean sources may, in a strict sense, be artesian in character and of importance as indicating the existence of larger supplies. You will oblige by filling up the accompanying blank, therefore, with as full and accurate information as you can command and return the same at your earliest convenience in the envelope inclosed herewith. This blank is for a single record. If you can fill others please make the fact known to the field agent in charge of your division.

Respectfully,

——— ———,
Special Agent in Charge.

U. S. DEPARTMENT OF AGRICULTURE,
ARTESIAN WELLS INVESTIGATION.

——— ———,
——— ———.

DEAR SIR: Please fill up and return inclosed blanks at your earliest convenience, using accompanying return envelope.

This request is made in furtherance of an investigation ordered by Congress into the extent and availability for irrigation of the subterranean waters. But a few weeks can be devoted to covering a large territory. In collecting the information desired only a limited time for inquiry and reports is made available. Hence, as this is for the public good, it is hoped that you will readily aid in obtaining the data required and that, too, in the shortest possible time.

Respectfully,

——— ———,
Division Field Agent.

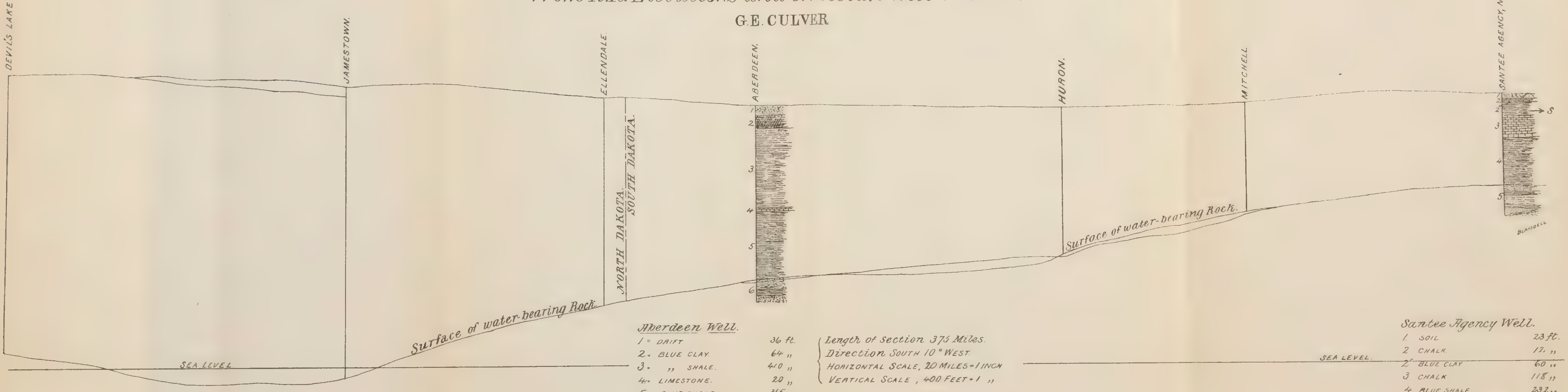
REPORTS OF DIVISION FIELD GEOLOGISTS.

Profile view from DEVIL'S LAKE *to* SANTEE AGENCY, NEB.

SHOWING RELATION OF WATER-BEARING ROCK TO THE SURFACE.

from R.R. Elevations and Artesian Well records.

G.E. CULVER



Aberdeen Well.

1 =	DRIFT	36 ft.
2.	BLUE CLAY.	64 „
3.	„ SHALE.	410 „
4.	LIMESTONE.	20 „
5.	BLUE SHALE.	365 „
6.	DAKOTA SAND STONE with SHALE PARTING.	60 „
	TOTAL	955 ft.

Length of Section 375 Miles.
Direction South 10° West.
HORIZONTAL SCALE, 20 MILES = 1 INCH
VERTICAL SCALE, 400 FEET = 1 „

Santee Agency Well.

1.	SOIL	23 ft.
2	CHALK.	17 „
2'	BLUE CLAY	60 „
3	CHALK	118 „
4	BLUE SHALE	232 „
5.	DAKOTA SAND STONE.	159 „
	TOTAL	604 ft.

REPORT OF PROFESSOR GARRY E. CULVER, UNIVERSITY OF DAKOTA, FIELD GEOLOGIST FOR NORTH AND SOUTH DAKOTA.

INTRODUCTORY REMARKS.

From the size of the district and the limited time available for field work, as well as from the purpose of the investigation, it seemed best to attempt only a general and necessarily rapid reconnaissance of the two States assigned to me. By this plan I hoped to be able to make a brief examination of all exposures of strata in either State likely to throw any light upon the question at issue, and so to determine, approximately at least, the controlling geological features and to outline roughly the artesian basin or basins lying in the two States.

Actual field work was begun May 1 and continued until June 12, and, although I traveled nearly 6,000 miles during this period, I was unable to visit all the points I had selected as likely to afford valuable information. I believe, however, that the course pursued has been justified, partly by the results already obtained and partly by the knowledge of just where future study is most needed.

With the exception of the exposures on the Missouri River, opportunities for studying the structure of the Dakotas are not abundant. The exposures are usually small and widely separated. Had accurate and complete records of the artesian well borings been kept, they would have furnished very valuable data. Unfortunately, this was not found to be the case. With some noteworthy exceptions, the only reliable data obtain able, referred to the depth of the well, the depth at which water was obtained, and the character of the water-bearing rock.

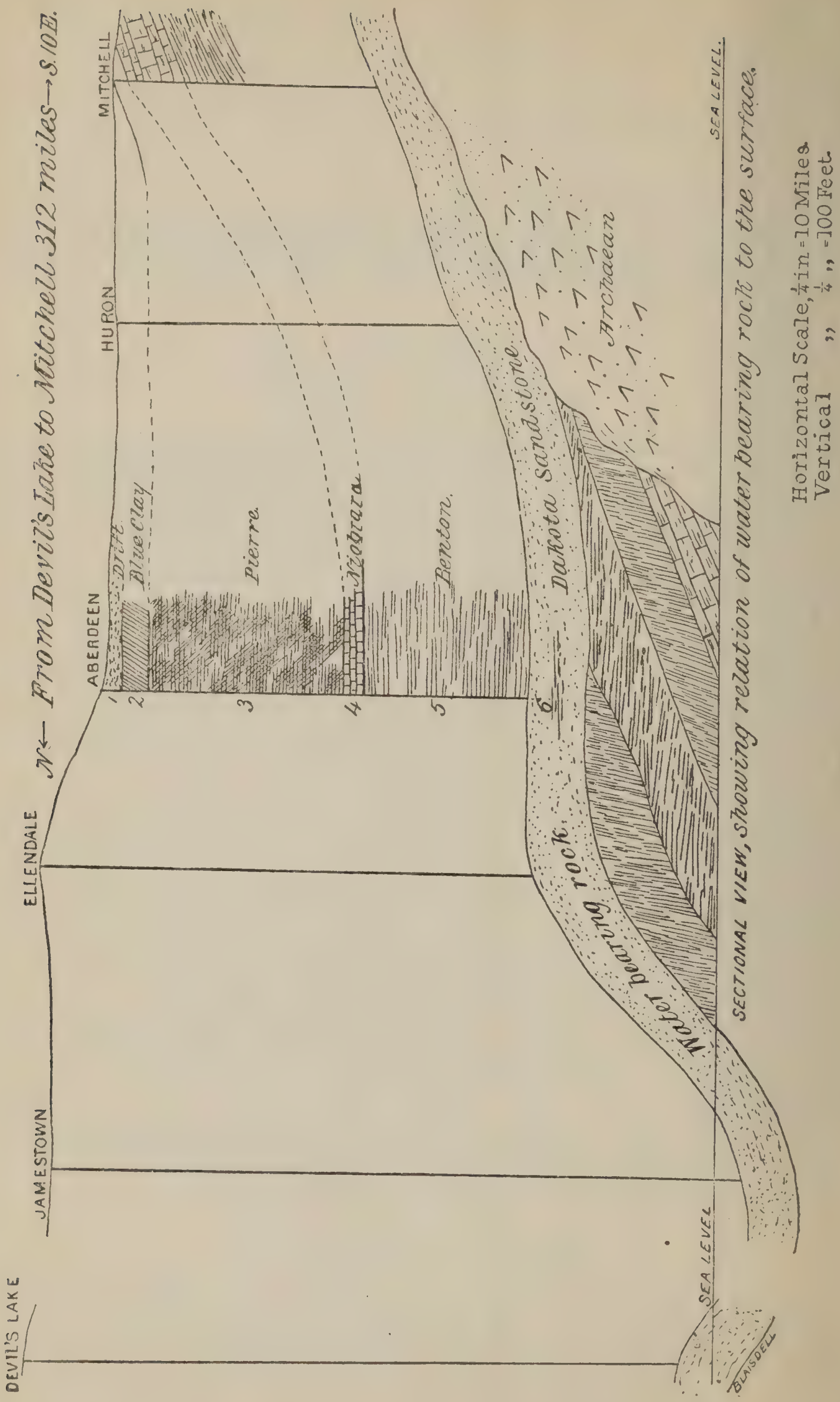
Using these facts, I have constructed the sectional view which accompanies this report, showing the relation of the water-bearing rock to the surface, in a line nearly north and south across the great artesian basin.

On the small scale necessarily used, the rock appears quite strongly folded, but when the length of the section is taken into consideration, it becomes apparent that the folds are such gentle undulations as to be quite inappreciable to the eye on the natural scale.

GEOLOGY OF THE DAKOTAS.

Archaœn.—The well-known Sioux quartzite, with a small area of diabase which outcrops on Split Rock Creek, in sections 15 and 22, Brandon Township. Minnehaha County, are all the rocks of this age occurring in either Dakota, exclusive of the Black Hills region.

The quartzite is most prominently exposed in Minnehaha County, where it is extensively quarried. The streams have cut deeply into it,


N← From Devil's Lake to Mitchell 312 miles→S.10E.
DEVIL'S LAKE
JAMESTOWN
ELLENDALE
ABERDEEN
HURON
MITCHELL
1
2
3
4
5
6
Drift
Blue Clay
Pierre
Niobrara
Benton
Dakota sandstone
Water bearing rock
Archaean
SEA LEVEL
SEA LEVEL
BLAISDELL
SECTIONAL VIEW, showing relation of water bearing rock to the surface.
Horizontal Scale, 1/4 in = 10 Miles
Vertical " 1/4 " = 100 Feet

notwithstanding its great hardness and durability. At Dell Rapids the Big Sioux runs through a gorge, the walls of which are about 50 feet high and usually perpendicular. Considerable portions of the upper layers of the rock have been carried away in the vicinity of the gorge, so that the whole depth to which the stream has cut is not less than 75 feet.

On the Split Rock, a small creek in the eastern part of the county, the quartzite forms vertical walls over 60 feet high, making a picturesque exposure. A number of fine springs issue from crevices in this rock, especially at Palisade, Corson, and Sioux Falls. I have not been able to get the amount of flow of any of them, but the city of Sioux Falls is supplied from a single spring, the largest, probably, of the number. At Sioux Falls the diamond drill has been sent into this rock about 600 feet, encountering nothing but quartzite, red shale, and pipestone. From the various smaller exposures of this rock, and from the record of well borings, it is seen that the quartzite lies comparatively near the surface in Minnehaha, McCook, Hanson, Davison, Lincoln, Turner, and Hutchinson Counties, and at no very great depths in the tier of counties encircling these, *e. g.*, at Vermilion, Clay County, in the university well, quartzite was struck at 630 feet; at Scotland, Bon Homme County, at 500 feet; at Plankinton, at 750 feet, and at White Lake at 850 feet. Its eroded surface is thus seen to slope somewhat rapidly to the south and west.

At Salem this rock is struck at 222 feet; Vilas, 466 feet, while at Iroquois, at this date, June 16, 1890, the drill is down 600 feet without finding it. It seems probable, therefore, that the counties referred to are the only ones in which this rock is likely to prove an obstacle in the way of obtaining flowing wells from the Dakota sandstone.

Granite.—At the foot of Big Stone Lake is an exposure of granite on the Minnesota side, extending down the valley of the Minnesota. No outcrop is known to the writer on the Dakota side. It is not improbable, however, that granitic rock would be encountered at no very great depth in the region adjacent to Big Stone Lake and south along the line in, say, the first tier of counties.

Cretaceous.—With the exceptions already noted, no rock older than Cretaceous has been encountered in the wells of the James River basin. (In the Red River Valley the older Mesozoic and Paleozoic rocks seem to have been penetrated.) The lower Cretaceous beds lap on to the quartzite in South Dakota, the Benton and the Niobrara overlapping the Dakota group. In the region of Big Stone Lake, Dakota, and in western Minnesota, the Cretaceous beds lap on to the older rocks. (See diagram.)

Beginning with the lowest of the Cretaceous series, the Dakota group, we find the only exposure in Dakota on the Big Sioux River, in the southeastern part of South Dakota, where it appears as a series of beds as follows: Sandstone, seam of lignite, sandstone, seam of lignite, sandstone, shale, sandstone. (See section view.) Throughout these beds impressions of leaves are abundant, and in places the seams of lignite become simply leaf-beds. On going up either the Big Sioux or the Missouri, the Dakota is seen to pass under the Benton shales in Union County, S. Dak.

Fort Benton group.—This group consists, on the Missouri, of blue, somewhat shaly limestone at the base, shales and laminated clays with some thin layers of very hard limestone, all of a lead-gray color, and about 90 or 100 feet thick altogether.

The limestone and the shales just above are full of the fossil remains of *Inocerami*, mostly *I. problematicus*.

The clays above contain *Pryoncyclus Woolgari, Mantell*, and one or two species of serpulæ. The former usually occur in concretions and the latter are usually found attached to pieces of a large bivalve shell. These three fossils seem to be quite characteristic of the Benton. Beside these may be mentioned as characteristic, crystals of selenite—often known locally as "isinglass"—concretionary masses of pyrite, (often the replacing material in the fossil pryonoyclus,) and large lenticular concretions of clay cemented by calcium carbonate into a rock of great hardness. These latter often contain disseminated pyrite, which of course adds to their hardness. They are often encountered by the drill in sinking wells, and are referred to by the drillers as "hard head," "iron ore," "conglomerate," etc. The Benton outcrops along the Missouri from the mouth of the Big Sioux to the mouth of the James below Yankton where it passes beneath the Niobrara group.

It is also exposed about 3 miles southeast of Mitchell in a cut on the line of the Chicago, Milwaukee and St. Paul Railway, where it is seen to pass under the chalk. It is probable that it lies in erosion hollows in the quartzite in the counties mentioned as being underlaid by that rock.

Niobrara group.—These beds, the somewhat well known "chalk rock," consist of marls, marly clays, and thick beds of light, friable, cream-colored limestone. The clays and marls are lead gray in color; the latter, however, sometimes weather to a light grayish white. From Yankton to Chamberlin, on the Missouri, the bluffs consist chiefly of these beds. East of the river they outcrop at various places from Chamberlin to Canton on the east line of the State. Mitchell, Scotland, and several points in Yankton, Clay, Turner, and Union Counties, are to be mentioned. Spirit Mound, 6 miles north of Vermillion, is the southernmost outlier on the Dakota side of the Missouri. On the Nebraska side the beds extend much farther south. At Chamberlin, where the bluffs are about 300 feet high, the lower 100 feet is Niobrara. Its total thickness can not be less than 200 feet in the neighborhood of the Missouri. Limestone, which seems referable to these beds, is reported in the sections of the wells at Huron, White Lake, Aberdeen, Columbia, Ashton, Andover, and Groton. Of course the wells at Mitchell, Scotland, Yankton, Tyndall, and the Santee Agency pass through it. At none of the places mentioned, however, is it reported at the thickness given above.

It is evident either that the beds thin out to the east or else that the marls, etc., are reported as blue shale. My own opinion is that both are true. Common fossils are *Ostrea congesta*, fragments of a large inoceramus, and numerous large scales of fishes. Fossil fish are less common.

Fort Pierre Group.—Dark unctuous clays constitute a great part of these beds at the typical exposure near Pierre. There are beds of dark-gray laminated clays at various levels. The whole group is quite thick on the Missouri, certainly not less than 400 feet, and probably much thicker. Taking the records of the wells in the northern part of South Dakota as evidence, the Pierre beds thin out rapidly to the east or else change their character more decidedly than they are known to do elsewhere.

Present knowledge leads me to think the former more likely to be

NOTE.—The subdivisions of the Colorado group are used here as being more specific. See Invertebrate Paleontology of the Upper Missouri Cretaceous. F. B. Meek.

true, and that the blue shale so uniformly reported from the northern portion of the basin belongs to the Benton and to the Niobrara.

The only exposure seen by me, except on the Missouri, referred to this group, was on the Cheyenne River, in the southeastern part of North Dakota, at Valley City. I found no fossils here, and was in some doubt, at the time of my visit, whether the clays belonged to the Benton or to the Pierre. If to the latter, then they lie in an erosion hollow of the Benton. The exposure consists of two beds, the lower dark-gray laminated clays, the latter black unctuous clays, unlike the Benton as seen on the Missouri near Vermillion, but much like some portions of the bluffs at Fort Benton, Mont.

The Pierre probably occupies a wide region in central Dakota in a belt running north and south. West of the river in North Dakota it is covered by later formations, but appears again in eastern Montana. Its most southerly extension is at Yankton, where I found a thin outlier capping the chalk bluffs near the cement works. In examining the bluffs above Yankton I find the Pierre rests on the chalk all along, under the Loess.

On the Firesteel north of Mitchell, occurs an outcrop of sandstone which I should have mentioned under Dakota, as it seems referable to that horizon, although differing from the typical Dakota somewhat. It consists of coarse yellow sandstone, perhaps 12 feet, then below red and very hard sandstone or grit, containing considerable quantities of imperfectly preserved wood, some carbonized and some silicified. The outcrop extends several miles to the northwest, but I did not have time to follow it. The exposure mentioned is not more than 5 miles northwest from the chalk which forms the bluffs of the Firesteel east of Mitchell, and rests on the Benton. Moreover, the sandstone and the chalk lie at almost exactly the same level. Further than this their relations were not determined.

In the eastern part of North Dakota, forming the western wall of the Red River Valley, is a thick bed of shale. The best exposure seen is at Milton, in Cavalier County, on the head waters of Park River, where it forms steep bluffs 150 feet high. Where it has been exposed to the air for a long time it breaks up into thin light-gray flakes of remarkably even size and quite hard. In this respect it differs from any cretaceous shales I have before examined. I succeeded in finding a few fossils here, the best an inoceramus, new to me, but plainly of this genus. Worm burrows were abundant. I also found what seemed to be casts of a little baculite. The specimens were poor, however, and unsatisfactory. Misleading information earlier in the season prevented my finding this rock until about the time I was compelled by the limited time to leave the field.

From such hasty observations as I could make, however, I am of the opinion that the shale is continuous with that which outcrops at Jamestown, N. Dak. I made an examination for fossils at the last-mentioned place, but found none. The general appearance and character of this shale is the same as that of the Milton exposure. The James at this point has cut about 100 feet into the shale, the valley being about a mile wide. South from Jamestown the shale is seen outcropping at various points as far as La Moure, near the south line of the State. No surface exposures were seen south of La Moure, in the James Valley, except those previously mentioned in South Dakota.

The deep wells at Jamestown and Devil's Lake show this shale to be practically continuous from the surface to the water-bearing rock, only very thin beds of limestone and sandstone being passed through

in either well, according to the reports of the drillers. This northward thickening of the shales is still further shown by the sections of two wells in Manitoba, kindly furnished by the Swan Company.

Laramie.—Passing west in North Dakota from the James River Valley, no exposures of strata are seen on either line of railway until the Missouri is reached. Here the Laramie is recognized. The river has cut into the beds about 200 feet, exposing the edges of alternating strata of clays and sandstone, with (at Williston) beds of lignite, silicified wood, etc. Near Bismarck a large tree was found in the clays about 175 feet below the surface, one-half of which (the lower) was finely silicified, while the upper half was part lignite and part brown wood. From a hasty examination it seemed to me that this portion was the result of the action of both processes, *i. e.*, it was partly carbonized and partly silicified.*

How far east of the Missouri the Laramie beds extend it is impossible to say until borings are made, as there do not seem to be any exposures.

The thickness of the beds could not be even approximately determined.

The Bismarck section is as follows:

	Feet.
1. Loess	30
2. Coarse sand	2
3. Shingle	6
4. Indurated clay (yellow)	30
5. Laminated clay (blue)	50
6. Arenaceous clay (yellowish)	20
7. Sandstone (gray)	20
8. Clay (blue)	50
LEVEL OF RIVER.	
9. Clay (blue)	50
10. Lignite	10
11. Clay (blue)	30
Total	298

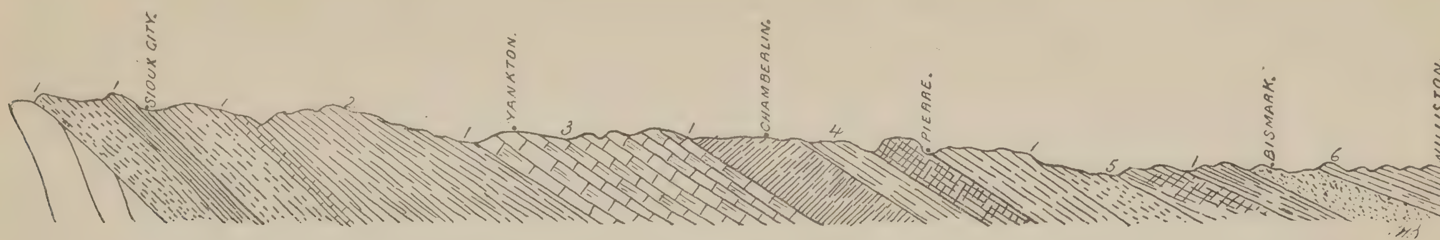
(The section below the river level was obtained from the excavations made by the Northern Pacific Railroad Company in building the bridge over the Missouri.)

The section at Medora, on the Little Missouri, is as follows:

	Feet.
1. Loess	23
2. Sand	2
3. Shingle	5
4. Indurated clay	17
5. Sandstone	2
6. Clay	24
7. Coal and underclay	2
8. Sandstone	40
9. Clay	3
10. Coal and underclay	1½
11. Clay	5
12. Sandstone	55
13. Clay	5
14. Coal	3
15. Clays	57
16. Coal	3
17. Clay	42
Total	289½

This is a fairly typical "Bad Lands" section. The clays are mostly arenaceous and the sandstones yellowish gray. Of course the coal is lignite. Many silicified stumps of trees occur. Far west in Montana the lower cretaceous beds rise again to the surface, the Dakota last.

* See Prof. Lester A. Ward's paper on the Laramie in sixth annual report, U. S. Geological Survey.



1 = DAKOTA. 3 = NIOBRARA. 5 = FOX HILLS.
2 = BENTON. 4 = PIERRE. 6 = LARAMIE.

Section on the Missouri from SIOUX CITY to WILLISTON.

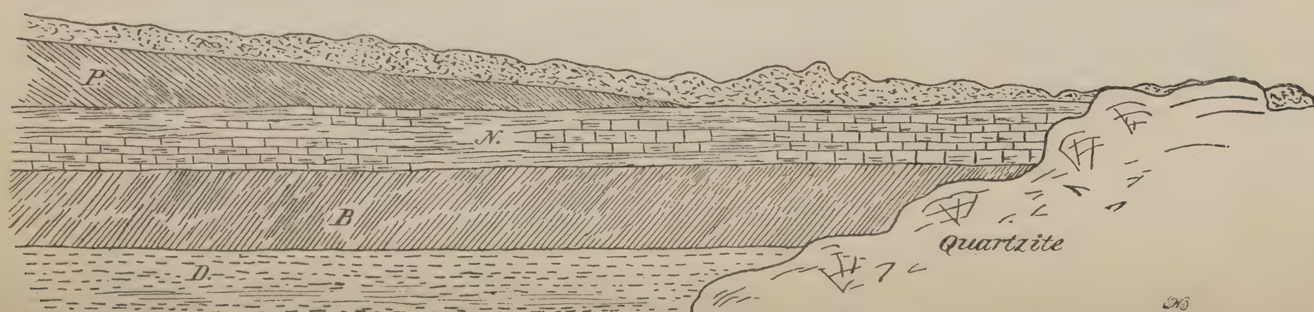
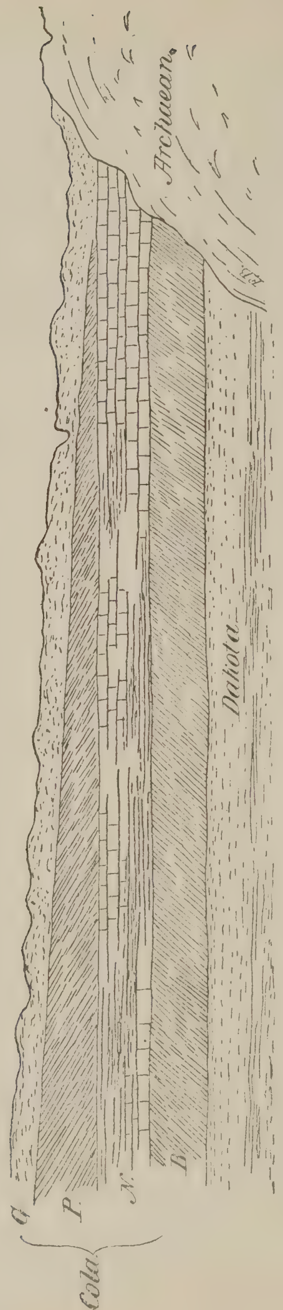
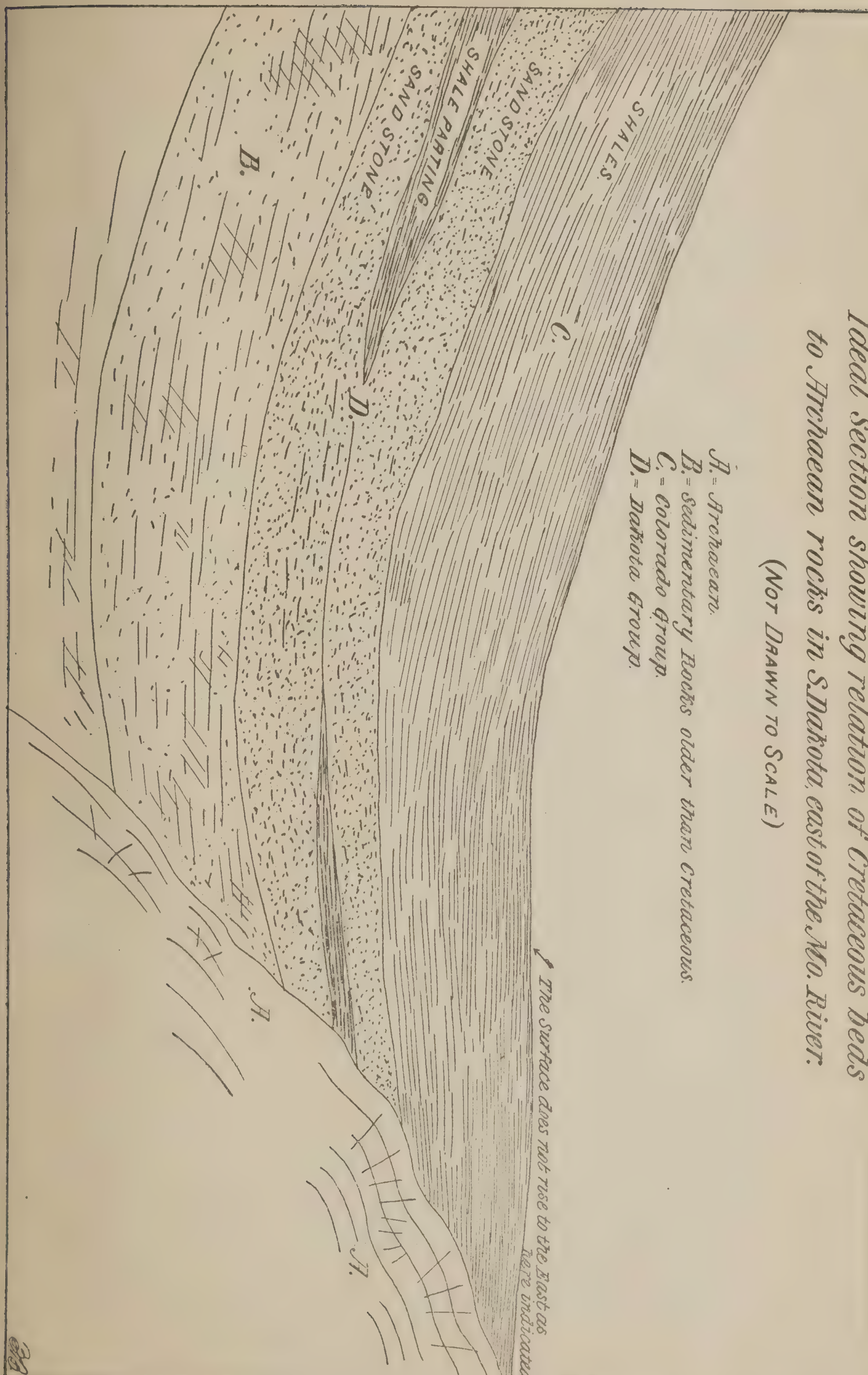


Diagram to show the overlap of the Colorado in S. Dakota.

D = DAKOTA, N = NIOBRARA.
B = BENTON, P = PIERRE.



Generalized Section illustrating overlap of the Colorado in S. Dakota.


Ideal Section showing relation of Cretaceous beds
to Archaean rocks in S.Dakota, east of the Mo. River.
(Not Drawn to Scale)
A.= Archaean.
B.= Sedimentary Rocks older than Cretaceous.
C.= Colorado Group.
D.= Dakota Group.
SHALES
SAND STONE
SHALE PARTING
SAND STONE
A.
B.
C.
D.
The Surface does not rise to the East as here indicated.

REPORT OF PROFESSOR G. E. BAILEY, M. E. PH. D., OF THE GEOLOGY OF SOUTH DAKOTA, WEST OF THE MISSOURI RIVER, AND OF WYOMING, EAST OF THE FOOT-HILLS OF THE ROCKY MOUNTAINS.

A careful examination of the geology of that portion of South Dakota lying west of the Missouri River, until reaching the foot-hills near the Wyoming line, shows that there is very little variation in the local particulars of the succession of the beds, in the texture and structure of the formation.

Sections taken along the Missouri River, along the Cheyenne River, White, and Wakpa Schicta Rivers, and the streams coming from the Black Hills, show that the chief requisite conditions for artesian wells exist throughout this entire area, viz:

First. A porous stratum, or water bearer, furnished by the Dakota sandstones.

Second. Impervious beds above and below the Dakota sandstones.

Third. A high fountain-head in the Black Hills and mountainous region along the western edge of the State.

The surface of all of that region lying east of the Black Hills and west of the Missouri River is almost wholly covered by the Colorado group of the Cretaceous, excepting a few local districts where fragments of the Laramie group, and even of the White River Tertiary, remain uneroded.

In the Black Hills there is an area of slates 50 miles wide by 90 miles long, surrounded in concentric rings by the various geological formations from the Carboniferous to the Dakota sandstones which form the outer wall of the entire range.

North of the Hills proper, this outcroping of the Cretaceous still extends beyond the north line of the State.

This region of mountainous country forms a large collecting area for the waters sinking into the Dakota group of sandstones, and forms the source of supply for the artesian waters of the region farther east.

The conditions upon which the artesian flow depends, as given by Professor Chamberlin in his report to the Government, are completely fulfilled in western South Dakota.

First. A pervious stratum to permit the entrance and passage of the water. This is furnished by the Dakota sandstones, which are essentially a body of coarse yellow or red sandstones from 250 to 400 feet in thickness.

Second. A water-tight bed below, to prevent the escaping of the water downward. This is furnished by the Jura Triassic system of rocks which lie immediately below the Dakota sandstones, and which are in substance as follows: Overlying the Carboniferous limestones is a deep

red clay that forms the bottom of the Triassic group of rocks. Beginning with this clay and ascending the strata are as follows: First 115 to 120 feet of red clay containing but little gypsum, and in some localities showing thin pieces of clay sandstone. Second, grayish purple and pink gray limestones 15 inches to 15 feet thick. Third, 200 to 300 feet of red clay with interbedded strata of soft shaly sandstones and pieces of gypsum. Last, it is not easy to point out the parting between the Triassic and overlying Jurassic as both vary considerably locally. In general the Jurassic consists of from 200 to 500 feet of gray ash-colored marls, with bands of green or red sandstones and with a few thin pieces of impure limestones.

Third. A like impervious bed above, to prevent the escape upwards. This is furnished by the Colorado group of rocks, which consists of dark gray laminated clays, alternating with layers of soft gray and light-colored limestones from 150 to 200 feet in thickness; lead-gray calcareous marls with light yellowish and white limestones, 100 to 200 feet thick; dark gray and bluish plastic clays, 150 to 250 feet in thickness.

The dark clays of this group form almost the entire surface of the region between the foot-hills of the Black Hills and the Missouri River, and which I find outcropping along the Missouri River at all the points which I examined from below Chamberlain to above Pierre.

Fourth. The inclination of the strata. While the rocks of the Black Hills pitch sharply from near the slates, their inclination rapidly grows less, until even in the foot-hills it is but slight, and as one goes east he soon finds the inclination or dip of the strata to have changed from a dip of from 10 to 15 degrees to that of 1 to 2 degrees, while over the greater portion of the plains, on what was lately known as the Reservation, the dip is generally from 1 to 2 degrees to the east, and possibly to the southeast a trifle. This gentle dip has carried the Cretaceous down slowly until it was replaced in the topography of the plains region in a few local districts by uneroded portions of the Fox Hill, which consists of gray ferruginous and yellowish sandstones and clays, having a total thickness of only about 100 feet, or else by a patch of the light clays and limestones of the White River Tertiary.

Fifth. A suitable exposure of the edge of the porous stratum for collecting the supply of water. The collecting area consists not only of the entire Black Hills but also of the ground having an elevation of from 5,000 to 6,000 feet above the sea, extending north and south of the Black Hills beyond the State lines. The hills have been subjected to a peculiar erosion which sends all of their drainage to the east, conveying the rain-fall directly against the edge of the Dakota group of sandstones which form the wall or rampart around the Black Hills, while the soft Jura Triassic is so eroded as to form a moat or huge ditch along the inner edge of the sandstones, and its clays aid in conveying and keeping the waters in the pervious bed above.

Sixth. An adequate rain-fall to furnish the supply. The elevation of the Black Hills, from 5.000 to over 8,000 feet above the sea, together with the heavily wooded interior, gives a much larger rain-fall than the districts farther east, as both the Government signal officers and a number of local observers, give the rain-fall as from 25 to 30 inches per year.

Seventh. Absence of escape of the artesian waters through local faultings. There is no evidence that the waters escape from the Dakota sandstones, as all the springs across the reservation do not evidently reach the artesian source below, but have their origin in higher and local sources.

The Dakota sandstones are admirably adapted to use as a water bearer, for they are not close-textured, but very porous, permitting the waters to permeate the whole bed, while their great thickness makes the supply beyond calculation. They are remarkably uniform throughout large areas of both Wyoming and Dakota where they have been examined. There is no evidence that they change anywhere from their coarse, open character to a fine-grained rock impermeable to water, but all the evidence is that they remain coarse-grained, with large water-conveying capacity and capable of furnishing a generous flow. Neither is there any proof that these sandstones thin out, but every indication that they maintain their thickness along the lines of the sections. (See Appendix.) And at the same time the impervious inclosing beds maintain their character and quality.

These facts, together with the gentle inclination of the strata to the east, *make the entire area from the foot-hills of the Black Hills region to the Missouri River an artesian basin.*

With the exception of the local districts covered by the uneroded portions of the Fox Hill, White River, and Laramie formations, which cover small areas to a sufficient depth to prevent the artesian waters reaching the surface after the sands had been penetrated, in general, the question of tapping of the artesian waters in western Dakota is one of local depth. Local depth depends on the amount of surface erosion to which the top shales have been subjected, and to the existence of the overlying Laramie Tertiary.

Unfortunately, no holes had been drilled in the entire field of my work, so that I have had no means of comparing the sections of the Cretaceous rocks as given in this report with the sections of any drilled holes. But I believe that the Dakota sandstones are the source of the artesian waters. Knowing that as it dips but slightly, it must lie within available reach of the drill in nearly all of South Dakota west of the Missouri, and that the question of the local depth is only the question as to the depth of the more or less eroded Colorado group above that.

In conclusion: The areas in which success may be reasonably anticipated are along the valleys of the Missouri, the valleys of the Wakpa, Schicta, Medicine, and American Creeks, and the White River Valley, the Cheyenne and Belle Fourche Valleys, and many large areas of table lands lying at a slight elevation above the various streams.

Second. There are areas in which the local conditions will have to be examined with more minuteness, in order to determine whether the hole is liable to be a success or a failure. This is especially true of the Upper White River region, of the lands immediately adjacent to the foot-hills, and the region between the hills and the Nebraska line. In all of these places there is evidence of more of less local faulting and disturbances of the strata.

Third. The areas in which the conditions are adverse and prohibitory to artesian waters are on the high divides along the old Pierre and Chamberlain trails, and most of the higher divides along the Cheyenne. The principal areas covered by rocks overlying the Colorado are found along the central portion of the old reservation near the Cheyenne River, which is covered by the Laramie group and shows valuable veins of coal; and by a district south of American Creek covered by the Fox Hill formation and along the upper White River by the White River Tertiary and Laramie formations.

Fourth. In the regions lying immediately south of the Black Hills, extending to the Nebraska line, the Tertiary rocks are undoubtedly liberal water bearers; they consist of thick, porous, coarse sandstones

closed beneath by the clays of the Colorado and Fox Hill groups, which have a slight dip, the same as the general surface of the land. It is not probable that the artesian flow is of any special pressure or power could be obtained from these rocks, owing to a lack of elevation at the collecting edge, still the amount of water contained in them is so much that in any wells sunk in them, the water would raise so near the surface as would make the matter of pumping an easy one. I would recommend the sinking of wells in this formation and having them tested by pumps, believing that their capacity would be sufficient to supply a much larger area than would be first supposed.

Fifth. The Dakota sandstones dip from the hills region south and southeast into the State of Nebraska and should furnish a water supply there provided the strata do not lie too deep for practical drilling.

Sixth. While it is evident that artesian water can be secured anywhere along the lines of settlement on the newly opened reservation, I would suggest the importance of having the Cretaceous formations carefully examined and studied through the Rosebud and Pine Ridge agencies in order to determine the dip and character of both Dakota sandstones and Tertiary rocks in order to settle the question of the artesian basins along the north tier of counties in the State of Nebraska.

Seventh. I would also suggest the importance of more careful study of the local Tertiary artesian basins in the southwestern corner of Dakota and in the northwestern portion of Nebraska.

WYOMING.

That portion of Wyoming lying north of the Platte River and east of the foot-hills of the Rocky Mountains would embrace almost the entire northeastern quarter of the Territory. The region is one of anticlinals and the corresponding synclinals, the entire region being covered by the various groups of the Cretaceous rocks to different depths; so far as artesian waters are concerned they require much more minute investigation than I was able to give in the brief time at my command.

There is no lack of artesian flow, as I have records of over sixty wells scattered along a belt of 45 miles wide extending from the northeast corner of the Territory to the center of Natrona County. Nearly all of these wells were flowing and the flow was either salt water, water heavily impregnated with sulphates and carbonates of soda, or else saline waters carrying a number of barrels of petroleum per day. In a few instances the borings were real oil wells, producing principally brown and amber lubricating oils, and in a few instances producing the light green oils similar to those of Pennsylvania.

Gas was quite common in nearly every well and in some instances shows enormous pressure.

Outside of this belt, especially along the east of the Big Horn Range and in a number of localities in Crook County and the eastern portion of Johnson County and in the northern portion of Laramie County, I am satisfied that careful examination would show the existence of a number of valuable artesian basins where good water could be obtained from the Dakota sandstone. In about one-third of the area of Johnson and Crook Counties and that portion of the southern counties

lying north of the Platte River the Colorado group of rocks covers the surface of the valleys, and I have no doubt but that a good artesian flow could be obtained in all such localities by drilling down to the Dakota, the only question being as to the value of the water when obtained; the probabilities are that it would be saline unless the flow of oil or gas was encountered.

In all this region the Dakota seems to maintain the same open, coarse character that it did in western Dakota, but as one approaches the Platte River and passes south along the east flank of Laramie Mountains towards Cheyenne, bands of fine-grained, impervious sandstone and quartz make their appearance in Dakota outcrop and might seriously affect its capacity as a water bearer. There are, however, thinner strata of more porous sandstone in the group which may yield a small local supply.

That portion of Wyoming adjacent to the Nebraska line, extending as far north as the Sioux City and Pacific Railroad, has another source of water supply which is not found in Dakota or northern Wyoming, namely, the Tertiary rocks and sandstone of the Tertiary are open and porous and well supplied with good water-tight strata below them. There is no impervious strata above. While no great pressure could be obtained in any well sunk in these sands, still they are such generous water bearers and so coarse in their texture that it might be found very profitable if wells could be sunk and the water raised to the surface by pumps; there is no doubt but the water would rise to near the surface of the ground in these rocks, and that the flow from a pump would be very large, but no artesian flow as ordinarily understood could be secured.

In this region where the rain-fall is comparatively limited and where Tertiary rocks receive their supply from the Rocky Mountains immediately to their west, I regard the development of the water in the Tertiary as of the utmost importance and only regret that there was not more time at my disposal to more thoroughly investigate it.

There is a third source of water supply, which is a large portion of northeastern Wyoming, especially in Johnson County along the line of settlements on the east flank of the Big Horn and the mesas along each side of the Powder River, also along considerable of the portion of the table-lands parallel to and north of the line of the Chicago and Northwestern Railroad from the Nebraska line as far west as Caspar, and along the valleys of the Caspar Creek, west and on the north flank of the Rattle Snake Range. The rocks of Laramie group are generous water bearers and sandstones furnishing a liberal supply of clear and pure water; as this formation in these localities is from 2,500 to 5,000 feet in thickness and has a sharp pitch, from five to twenty-five degrees, wherever water is obtained it comes with good pressure. The question of depth of the water supply in this formation is wholly a local one, varying with each township almost, and it would require protracted and minute investigation to give any detail in connection to its value as a water producer.

I would respectfully call attention to the following suggestions:

First. That a careful examination be made of that portion of Wyoming lying east of the Big Horn Mountains and north of the Rattle Snake, Caspar, and Laramie Ranges and east of the Rocky Mountains proper in the regions south of the Platte River, as but very little work has ever been done in any of this region by Government geologists for any purpose.

Second. The Dakota sands in the north portion of the Territory are open and porous and liberal water-bearers, and all the districts where they are covered only by the Colorado rocks should receive a careful examination.

Third. The Tertiary rocks along the east edge of the Territory, especially near the Nebraska line, could no doubt be made liberal producers in many localities, provided careful and thorough study is made of them.

Fourth. Along the principal lines of settlement the Laramie group will be found to be the main source of artesian-water supply, but owing to the sharp folding of the synclinals it would require considerable time and study to define the area of the basins and ascertain its value.

Fifth. The borings so far made show that the Territory will in all probability become famous for its oil wells, as well as salt and gas, developed by boring for artesian water.

REPORT OF PROFESSOR LEWIS E. HICKS, STATE UNIVERSITY OF NEBRASKA, ON THE STRATIGRAPHY AND HYDROLOGY OF NEBRASKA.

I.—SCOPE OF THE GEOLOGICAL INVESTIGATION.

Almost all the subterranean waters of Nebraska have a tendency to rise in wells and bore-holes, sometimes flowing out at the surface, and hence come within the scope of "artesian" as defined by the Department of Agriculture. As a geologist it falls to me to describe the stratigraphic conditions which determine the direction of flow and the pressure of subterranean waters, rather than to make an enumeration and description of flowing wells. Some of these will be incidentally described and their position indicated on the map, but this will be more for the purpose of illustrating the general principles of the underground circulation of moisture than as aiming at an exhaustive catalogue of such phenomena.

II.—SOURCES OF MOISTURE.

The water which flows on the surface or traverses the porous rocks beneath the surface of Nebraska is derived from the annual precipitation of rain, snow, and hail and from inflowing waters, partly on the surface, but more beneath the surface.

THE RAINFALL.

For the ten years preceding and including 1887, the mean annual rainfall of Nebraska as reported by Prof. Godwin D. Sweezy, in the Report of the Nebraska State Board of Agriculture for 1887 (pp. 27 *et seq.*) was 28.49 inches. This was the average of thirty-two stations, of which twenty-two were in southeastern Nebraska, where the rainfall is greatest. The average for western Nebraska is about 20 inches. This would be sufficient for most crops if it fell in good season and in gentle showers. But it is unfortunately rather spasmodic, several inches of water—even as much as one-fourth of the whole annual precipitation—sometimes falling in a single storm, and long periods of drought or of scant precipitation intervening. During great storms the atmospheric phenomena are very intense, the winds are violent, electric tension is great, oppressive heat is followed by sudden cooling, and much of the moisture is congealed into deadly hail instead of vivifying rain. It is believed that irrigation and the growth of trees will modify the intensity of storms, prevent destruction of crops by hail, and secure more frequent, gentle, and regular precipitations.

The aggregate volume of water precipitated is enormous. It amounts to more than 100,000 cubic feet on each acre, or 5,000,000,000,000 cubic feet annually for the whole State. The mean annual discharge of all the rivers of Nebraska is about one-fourth of this amount, and it might be supposed therefore, that the flow of these streams is entirely due to the rain fall here. But evaporation is the thief which robs us of our rain-fall. Annual evaporation from a water surface freely exposed is certainly twice as great, probably it is three times as great, as the rain-fall on the Great Plains. Plants absorb and transpire large quantities of moisture. Much of the rain-fall which escapes evaporation never reaches the rivers. It is absorbed in the soil, which drinks up the showers as fast as they fall. This occurs to a far greater extent wherever the prairie sod has been broken up by cultivation, and it is a most beneficial process. The soil and subsoil acquire a circulating capital of vivifying moisture. Gravitation draws this moisture downwards, and this movement prevails so long as new supplies are received at the surface. But upon the drying of the surface the opposite force of capillarity comes into play and pulls the moisture up to nourish the growing crop.

When we consider all the demands which the rain-fall has to meet, and especially the great and constant one of evaporation in a land of clear skies, hot sun, and brisk winds, it would be surprising if so much as one-fourth of the water descending from the heavens were found flowing in the streams. We know indeed that the streams of Nebraska derive their waters in part from the rains and melting snows in the distant mountains. This accession of moisture comes partly on the surface and partly by way of the porous rocks beneath the surface. The North Platte delivers a large volume of water into the State. The South Platte formerly did, but irrigation in Colorado has reduced its channel in Nebraska to a dry sand-wash over which teams may be driven the greater part of the year. Other streams entering Nebraska add something to the surface flow. But the underflow along the inclined beds of porous rocks is undoubtedly a more important source of moisture than all the rivers which enter the State. At many points along or near the western boundary these subterranean waters have been tapped by wells or show themselves in springs. More than one level of "sheet water" has been demonstrated, and the deeper veins have the greater pressure.

Many streams have a steadiness of volume, and that volume unaccountably large, if the rain-fall of their several basins be regarded as the only source of supply, which indicates that they have eroded their channels down to the level of some sheet of water which feeds them with perennial springs, and maintains a steady volume in spite of long-continued drought. Take, for example, Frenchman River, the chief affluent of the Upper Republican River. It has a catchment basin of about 700,000 acres, upon which 38,000,000,000 cubic feet of water falls each year. More than one-third of this amount is delivered by the Frenchman to the Republican, and it flows on with very little change, month by month and year by year, without regard to variations in the rain-fall. A smart shower may fall in that region without starting any surface flow upon the parched slopes and table-lands to swell the volume of the stream. In order to maintain so large and constant a volume it must be fed from subterranean sources, and observation of its headwaters discloses the actual existence of numerous and strong springs of a perennial character.

A further evidence of the existence of subterranean waters flowing into Nebraska from without is the patent fact that there are flowing

wells, some of which do indeed obtain their waters from the rain-fall within our borders, but others have such relations to the folded strata as to make it clear that their sources are in the remote plateaus and mountain ranges. In brief, we have three distinct indications of a considerable underflow apart from that belonging to each river, viz, ordinary wells tapping sheet water, perennial springs, and flowing wells. The cause of such an underflow is readily detected when we examine the dip of the rocks and see that they are not only inclined, but that porous beds are so shut in between impervious beds as to provide a natural system of water carriers. This brings us to our third topic, the lay of the rocks, which is the key to the whole matter of underground circulation of moisture.

III.—GEOLOGICAL STRUCTURE AND SURFACE FEATURES OF NEBRASKA.

Broadly stated, the structure is that of a single broad synclinal trough, whose western rim is raised some 3,000 feet above the eastern. (See Fig. 1.) Of course this broad view of the case, and the rude diagram which illustrates it, ignores the minor crumplings and tiltings and all of the unconformities of the strata. These may be safely ignored in the general discussion; and in this preliminary report of an investigation so limited in time as the present one, nothing but general statements, illustrated by a few specific cases, can be made. The minor folds and the unconformities caused by erosion may turn out to have an important influence when the subject is investigated in its minute details; but for the present general discussion it is substantially correct to say that Nebraska is one broad synclinal. The axis of the trough is not quite a north-south line, neither is the dip exactly east or west.

In eastern Nebraska the dip is west-northwest; in western Nebraska it is east-southeast. The axis of the synclinal consequently runs north-northeast and south-southwest, being at right angles to the dip..

This synclinal structure brings up the older formations in the southeast (see geological map); the newest rocks are found near the center of the State; and older rocks again emerge as we go westward up the slopes of the mountains. In the process of upheaval of the Rocky Mountains the whole series of strata in Nebraska not only got bent, but tilted away from the axis of elevation, and at the same time several beds of sand and gravel were formed, which are the water-carriers for western Nebraska. This tilting also determines the character of the present surface of Nebraska, which is that of a great plain sloping gently to the eastward, or southeast by east, nearly in the same direction as the dip, but not conformable with the dip of the rocks, because erosion has cut deep valleys, the bottom of the basin has been filled in with later sediments, these being again cut by streams, and again a mantle of fresh sediment thrown down. This process has been repeated several times, and the existing surface is a complex result of many and varying forces acting through long periods. Neglecting minor topographic irregularities the surface may be regarded as a plane sloping southeast by east at the rate of 10 feet per mile. Then, since the dip is expressed by a curve, the surface plane cuts the dip, as shown by the line *a b*, Fig. 1. This diagramatic representation, regarding the surface as a geometric plane, differs considerably from an actual profile, but it exhibits the physical and hydrographic relations of the surface to the geologic structure with substantial accuracy. An actual profile would not only show the unevenness due to erosion, but would, instead of a

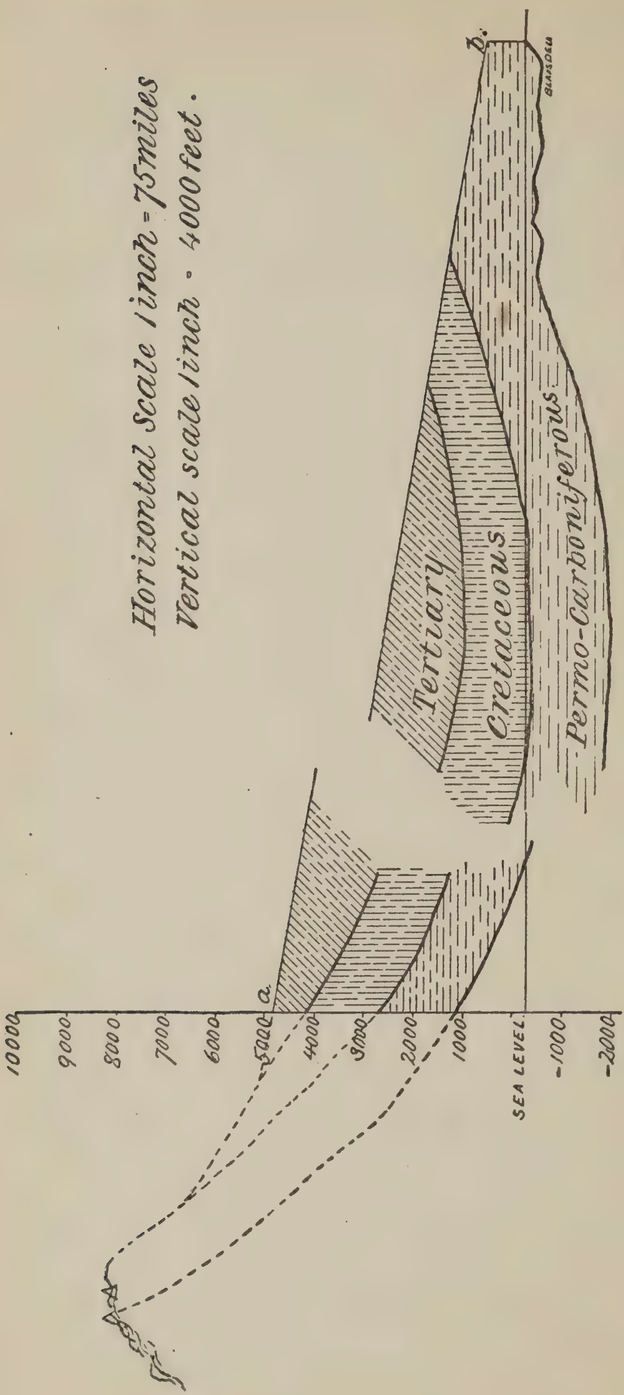
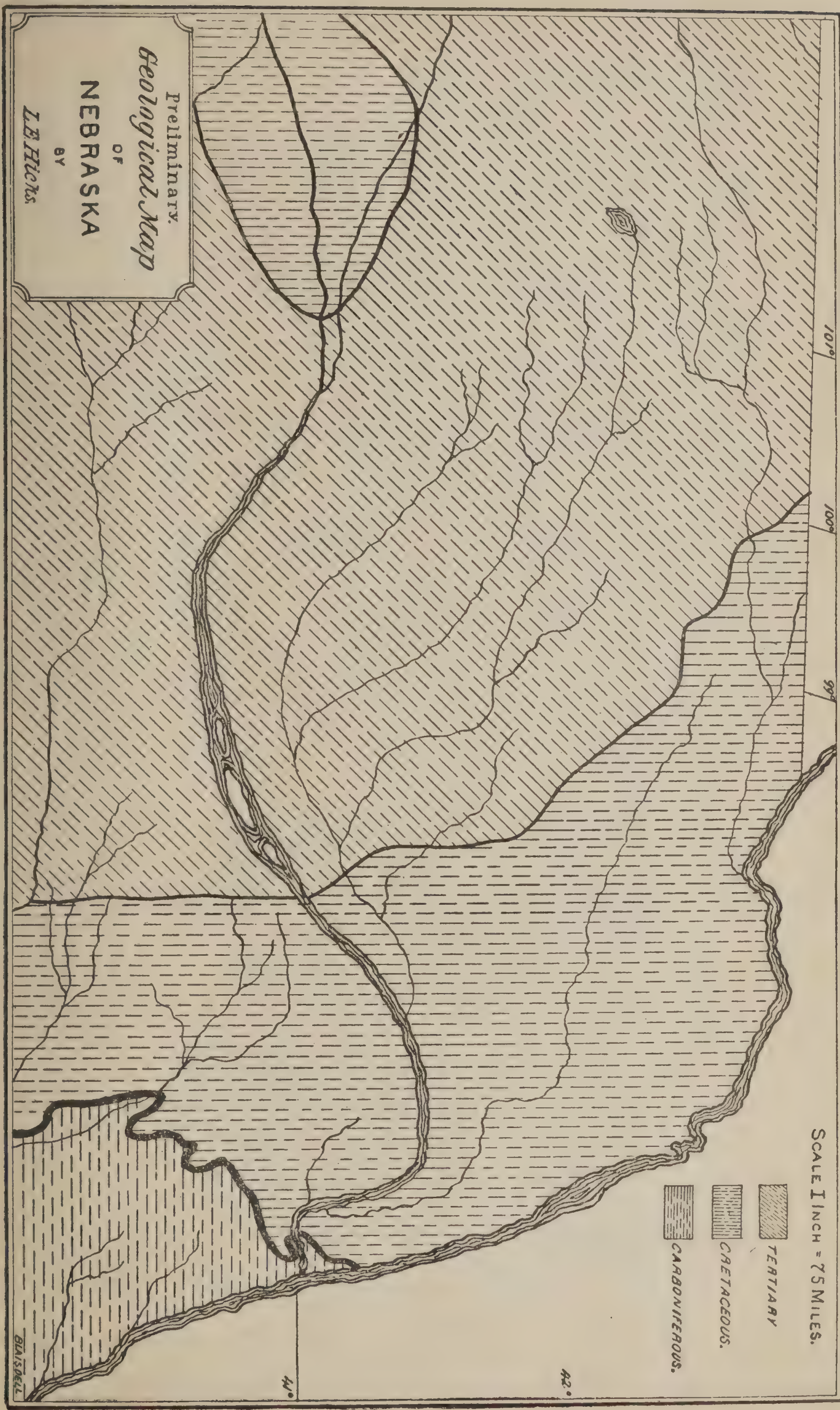


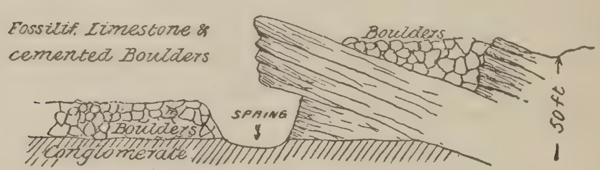
Fig. 1.
Diagrammatic Section of NEBRASKA from SIOUX COUNTY,
E. S. E. to RICHARDSON, CO.


Preliminary.
Geological Map
of
NEBRASKA
by
L.E. Hicks.
Scale 1 Inch = 75 Miles.
TERTIARY
CRETACEOUS.
CARBONIFEROUS.
101°
100°
99°
40°
42°
BLAISDELL

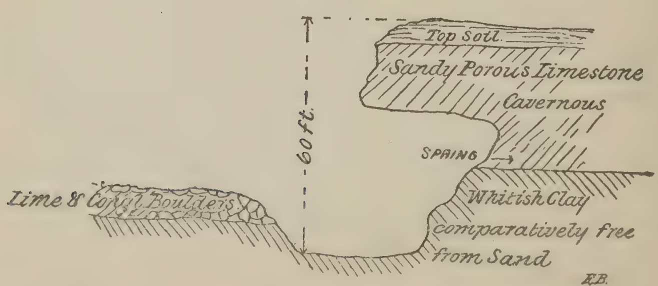
uniform slope, show a somewhat steeper gradient in the western than in the eastern portion of the line. A profile in the north-south direction would exhibit the unevenness due to erosion much more strikingly because it would cut across the valleys and show the table-lands rising from 200 to 800 feet above them.

The existence of these table-lands and the peculiar forms on their surface have an important bearing upon the underflow in Nebraska, and hence merit a brief description. On the typical table-land there are no streams whatever. Many square miles of western Nebraska are of this character. Not only are there no streams upon the table-lands themselves, but the waters falling there do not feed the streams in the valleys, unless it be by the indirect course of subterranean waters and springs. This statement may seem incomprehensible to readers who are accustomed only to the ordinary topographic types produced by water sculpture in which every part of the surface belongs to the drainage basin of some stream and the water partings are sharp lines. Here the whole broad table-land is the water parting. Its slopes at the edges turn the water off either way, but its whole summit constitutes a hydrographic unit independent of any river basin. The surface is not formed by water-sculpture or wind-sculpture, but is a primitive surface of deposition. The old lake bottom was uneven by reason of previous erosion, and the traces of ancient valleys, partially obscured by new sediment, remain in many places. These valleys are a puzzle to the traveler uninitiated into the secrets of successive cycles of erosion and deposition. There is the valley plainly enough, but where is the stream that excavated it? Buried and forgotten! The old river may be resurrected, as many others have been, by the progressive establishment of a new drainage system, the existing streams re-opening the primitive silted-up channels, but some of them will never be restored.

SECTION OF BIG SPRING



SECTION OF MOSS SPRING



Another topographic type of the table-lands, and by far the most significant and important one, is the lagoon. This is a natural basin with rim complete on all sides and rising from 1 foot to 50 feet above

the depressed center. These lagoons are very numerous, sometimes as many as twenty upon a square mile. They vary in size from 1 acre to several hundred acres. The cross-section (Fig. 2) shows a broad, shallow basin filled with muck in the center to the depth of from 7 to 20 feet. A shallow pond with aquatic vegetation may occupy the lowest part at all seasons, or only in wet weather, or it may be wholly obsolete.

Fig. 2.

Cross Section of a Lagoon

a a Black muck.

b b Tertiary marl.

Many of the lagoons have been utilized for domestic supply by means of deep cisterns cemented and covered to prevent evaporation; and a still greater number are used for stock-water, the natural depression being deepened with plow and scraper. The influence of the lagoon form upon subterranean waters is obvious. All the rain-fall of such region which escapes evaporation sinks into the earth instead of flowing off in surface streams.

The lagoon form is a record both of pre-existing inequalities and of uneven deposition of sediment. If western Nebraska should again become a lake bottom, and 100 or 200 feet of sediment be slowly and unevenly sifted down over the valleys and sand-hills, we should have a series of smothered rivers, silted-up valleys, and undrained lagoons, very similar to the existing table-lands where they have not been invaded and modified by the modern water-ways. Such a surface being again elevated and converted into a land area, would begin to form new waterways, and ultimately attain the ordinary topographic type of a country formed by water sculpture. Since western Nebraska presents a mixed or intermediate type in which water sculpture mingles, contends with, and impinges upon areas of unmodified primitive deposition, it is manifestly in a transition stage. Running water is the chisel which has shaped the features of all the older countries, and it has attacked this region but has not yet had time to reduce the whole surface to the valley type. Thus topography confirms the verdict of geology that this region is a newly-formed terrane.

The sharp transition from table-land to river valley is another evidence of the recent emergence of the land. Erosion is sharp and active in the intermediate belt along the edge of the table-land. The blanket of lake sediment is frayed out, fretted, and fringed with an intricate maze of rugged cañons. This belt is difficult to traverse and incapable of cultivation. The soil of the table-lands is excellent. That of the valleys ranges through all degrees from the best to the most worthless. Here in the valleys we meet with additional evidence of the newness of the country in a geological sense. In old countries (geologically old) the valley or bottom lands are the best. The long-estab-

lished order of things results in rich and deep beds of alluvium produced by the copious vegetation in the well-watered valley. The new valley, on the other hand, is encumbered by wash from its naked walls. Especially in a region of light rain-fall, where vegetation is tardy in its work of healing the gashes made by the water of occasional storms in the new and unconsolidated beds, the valleys are constantly deluged with fresh silt, and the accumulation of organic matter is slow. The valley lands are in many places sandy, in some places alkaline, and are, generally speaking, inferior to the table-lands. Particular fields, however, and some broad stretches of bottom land in western Nebraska, excel in fertility. Moreover the amelioration of the bottom lands by natural agencies is proceeding rapidly, and may be greatly accelerated by intelligent effort. Many square miles of river bottoms which formerly lay bleaching in the sun, or whirled about in sand-storms, are now converted into verdant meadows.

In the region of sand-hills, as well as on the table-lands where the lagoon form predominates, the rain-fall goes to feed the underflow. Sand-hill topography is like that of the unmodified table-lands in presenting a series of closed basins independent of drainage. These basins are, however, very different from the lagoons both in origin and character. The lagoon was formed by the settling of sediment in water upon a surface already uneven. The closed basin of the sand-hill region is formed by cross-ridges due to shifting winds. The typical form of a sand-hill is the elongated half-cone (Fig 3). The base is cut

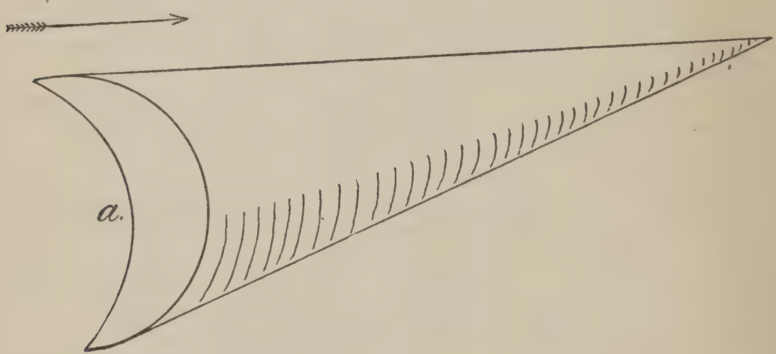


Fig. III.

Typical form of Sand Hill.

"Blow-out" at a.

Direction of wind indicated by the arrow.

off obliquely, has a deeply concave surface, faces to windward, and forms a "blow-out." The tapering cone stretches off to leeward, or merges into the next blow-out, thus forming elongated ridges whose jagged, saw-tooth summits indicate the successive blow-outs. The direction of the ridges is governed by the prevailing winds, and since these are from the west or southwest, the tendency to east-west ridges, with blow-outs facing west, is plainly apparent. But shifting winds

give cross-ridges and closed basins. The sand-hills are full of these, some of them being occupied by small lakes. Sand-hill topography, or wind-formation, is therefore another type independent of surface drainage, and the absorptive nature of the sand makes such regions very important feeders of the underflow.

In eastern Nebraska the whole surface is formed by water sculpture; there are no closed basins of any considerable extent, and the bottom lands are highly fertile, except the few spots which are marred by swamps or by "gumbo."

IV.—WATER-BEARING STRATA.

The porous beds through which the subterranean waters flow occur at several different levels and are composed of rocks of various kinds, ranging in degree of porosity from coarse gravels to fine sandy marls and limestones. Beginning with the Permo-Carboniferous, the oldest formation in Nebraska, the water-bearing rocks will be described in ascending order from the oldest to the newest. The order of economic importance is just the reverse of the order of deposition, that is to say, the oldest rocks are the least valuable as bearers of water for irrigation, and the newest rocks are the most valuable.

(1) THE SANDSTONES AND LIMESTONES OF THE CARBONIFEROUS.

An artesian flow has been obtained from Carboniferous rocks at various points in Nebraska, and plenty of water from the same formation in other places where the force was not great enough to create a flow. Contrary to what one would naturally expect the limestones of the Carboniferous appear to yield more water than the sandstones. The limestones are water-bearing wherever they are coarsely crystalline or cavernous from the removal of fossils by solution, or much divided by fissures. Porosity due to crystalline structure is most frequently observed in dolomitic or magnesian limestones. Thus, for instance, artesian water flows from crystalline magnesian limestone at a depth of 545 feet in the Government square just north of the post-office in Lincoln. The well mouth is 1,170 feet above tide, and the top of the water-bearing stratum is therefore 625 feet above sea-level. The water is salt (10° by the salinometer), and carries also a large amount and variety of other mineral matter in solution.

Two miles west of Lincoln, on the south shore of the salt marsh, brine of 17° strength flows from a reddish, friable sandstone at the depth of 600 feet, and a weaker brine from limestone at a depth of 823 feet. The well mouth is 1,138 feet above tide, so that the upper vein is 538 feet and the lower 315 feet above tide water.

In the test well (for coal) at Brownville, Nemaha County, brine was obtained from sandstone at 263 feet (630 feet above tide) from magnesian limestone at 599 feet (294 feet above tide), and again from magnesian limestone at 820 feet (73 feet above tide).

The prevailing saline and highly mineralized character of the waters obtained from the Carboniferous rocks is just what we might expect from the fact that they dip below sea-level in the middle of the basin, and the water traverses long distances in contact with minerals more or less soluble. The conditions of artesian flow are perfectly fulfilled in this older formation (see Fig. 1), and the pressure and volume are accordingly ample. But the waters have no value for irrigation, and they are mentioned here only to illustrate the general laws of underflow in Nebraska.

(2) THE SANDS AND SANDSTONES OF THE CRETACEOUS.

Lying unconformably upon the Carboniferous formation is a series of strata of the Cretaceous period, which is also bent into one grand fold, having its porous members exposed to percolating waters over a considerable area where they crop out on the slopes of the mountains. The lower member of the Cretaceous, the Dakota, is the water-bearing member, and its sands and sandstones are so permeable, and so shut in by impermeable clays and shales as to create flowing wells, which occur along a belt running from Jefferson County to Cedar County. The conditions of their flow will be readily understood from figure 1. Near St. Helena, in Cedar County, good fresh water flows with strong pressure from loose sand, or very soft sandstone, in the upper portion of the Dakota, at the depth of 450 feet (1,400 feet above tide). A flowing well deriving its waters from Dakota sands formerly existed at Seward, Seward County, but I have not been able to obtain any other data respecting it than the bare fact of its former existence. At Lincoln brine of 35° strength was obtained in the test well at the salt marsh in sand and gravel at the depth of 195 feet (943 feet above tide). This was at the bottom of the Dakota, where it lies on the eroded surface of the Permo-Carboniferous. The brine rose within 3 feet of the well-head, but did not flow out. The Rice pumping station, supplying water to the city of Lincoln, though not a flowing well, deserves mention on account of the large volume and excellent quality of the water. It furnishes one and one-quarter millions of gallons daily. This is derived from sandstone of the Dakota group, at a depth of 75 feet (1,100 feet above tide). At Fairbury and Reynolds, in Jefferson County, are flowing wells in the Dakota yielding salt water, but detailed records of the borings have not been obtained.

All the wells mentioned above are on the eastern outcrop of the Dakota, or at least very near it. The Cedar County wells penetrated some 400 feet of chalk and shale of the Colorado group before reaching the Dakota. Whether this formation may be made to yield its treasures at the surface farther west where the water is needed for irrigation is a question worth investigating. It has been said that the Dakota lies too deep. My own diagram (Fig. 1*) represents it.

(3) THE SANDS, SANDSTONES, GRAVELS, CONGLOMERATES, AND SANDY MARLS OF THE TERTIARY.

It has been assumed hitherto that the only chance of obtaining flowing wells for irrigation in Nebraska was by penetrating to the lower member of the Cretaceous. But the most cursory investigation reveals several levels of "sheet" water nearer the surface in the porous beds of the Tertiary. None of these, it is true, have as yet proved to have

* It should be remembered that the Dakota is the lower member of the Cretaceous. In judging of the depth of the Dakota the lower portion of the space assigned to the Cretaceous in Figure 1 must be referred to. Measures taken from that to the line *a b* will give the approximate depth of the Dakota if there are no subordinate folds as lying deep; but this is on the assumption that the observed dip continues far to the east from the western outcrop and far to the west from the eastern outcrop. If there are any local anticlinals within the great synclinal, and such a structure is extremely probable, in such places the Dakota will lie nearer the surface and may yield valuable flowing wells at moderate cost in regions where the water will be available for irrigation. Inasmuch as this is a proved and well known artesian basin, experiments designed to determine its extent beyond what is now known of it would be a very different matter from blind groping for subterranean waters among unknown rocks.

the force of flowing wells in this State, except a single well near Crawford, in Dawes County. Nevertheless the Tertiary basin is a very promising one for western Nebraska. The volume of subterranean waters is strong and constant. The upper veins lie so near the surface that

M. N. Table land of Sioux Co.
a. b. Stratum of sandy marl reached by wells.
Dip, S.S.E. Springs at b.
Figure 4. Relation of Springs to Sheet Water.

they may be directly utilized by pumping. The deeper veins rise to a higher level, when tapped by borings, than the higher ones, and the probabilities are strong that some of them will flow at the surface.

Most of the geological and physical conditions of artesian wells are fulfilled. The rocks lie in basin form. The porous members are widely exposed to receive moisture. The area of the Tertiary is 54,000 square miles in Nebraska alone, and the catchment area extends into the adjacent States and Territory. Not less than two and one-fourth trillions cubic feet of water annually falls upon the Tertiary in Nebraska. Much of the surface upon which it falls is occupied by table-lands, whose closed valleys and lagoons deliver to the underflow all that escapes evaporation and absorption in organic tissues. The porous strata alternate with impervious clays, marls, and limestones, which furnish floor and roof to the water-carriers. The whole series of beds inclines gently to the east.

All these are favorable conditions for flowing wells, and it may seem desirable rather to account for the fact that as yet they do not occur than to multiply reasons for expecting them hereafter. It is only the upper veins that have been penetrated thus far, and these are intercepted by the erosion of the valleys, which circumstance alone would be sufficient to defeat the accumulation of pressure. It is possible that even the deeper veins are not sufficiently shut in at the eastern outcrop. The eastern rim of the rock basin is low, and the pressure may be relieved by outflows there in the form of springs. Again, the floor and cover of the water-bearing strata may not be sufficiently impervious to shut in the water and prevent percolation upward and downward whenever the pressure becomes considerable.

Even with imperfect barriers to prevent the escape of the water and the dissipation of hydrostatic pressure, we may still have a flow from the Tertiary basin on account of frictional resistance to the flow along the dip. The line of least resistance may be to ascend in an open borehole against gravity, instead of traversing long distances in strata not perfectly porous.

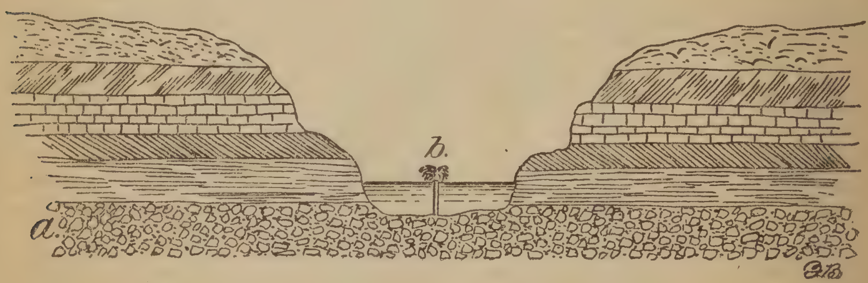


Fig. V.

Springs rising in the bed of a stream.

a. Water bearing gravel

b. Spring in bed of Stream.

But whatever may be the chances for flowing wells, at all events considerable supplies of water course along the permeable beds of the Tertiary, beneath land which is much in need of it. The chance of flowing wells is good enough to merit further investigation and experiment, and, if this chance should fail, the waters are not too deep to be economically raised by machinery.

The presence of sheet water has been demonstrated in all the western countries at depths varying from 50 to 500 feet. It always rises considerably, sometimes nearly to the surface. *In William G. Arnold's

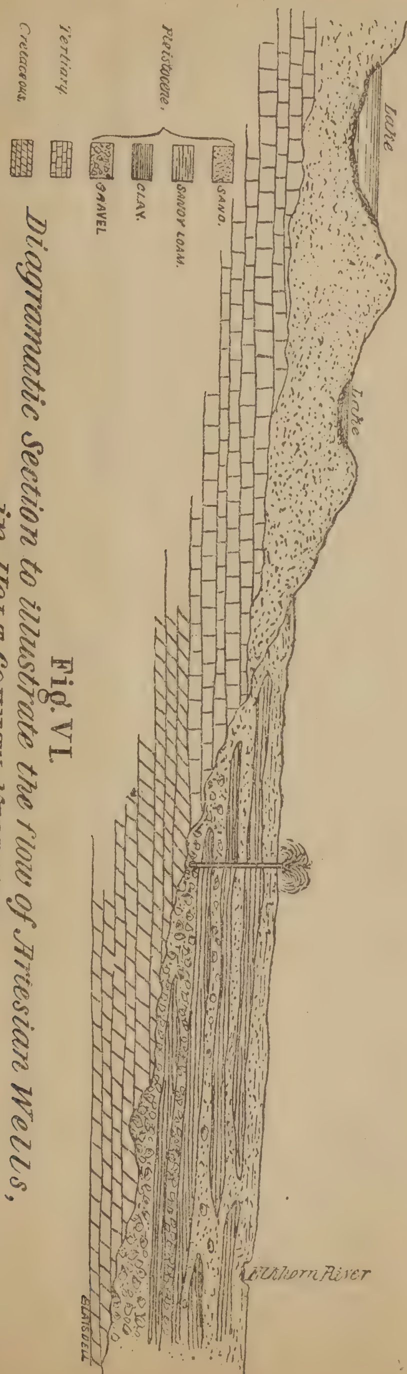


Fig. VI.
Diagramatic Section to illustrate the flow of Artesian Wells, in HOLT COUNTY, NEBRASKA.

well, section 18, township 8 north, range 41 west, the first vein was struck at 100 feet, and rose 4 feet; the second vein at 120 feet, and rose 32 feet; the third vein at 135 feet, and rose 54 feet, *i. e.*, the water from the lowest vein rose 15 feet higher than that from the highest vein. This illustrates the force of the water in the deeper strata.

The water-bearing stratum is usually gravel, of which there are numerous lenticular sheets in the old lake basins, formed in periods of transition from land to water, or *vice versa.* In some cases it is loose sand, sandstone, conglomerate or sandy marl which carries the water.

The supply is reported "inexhaustible" in many places. This only means, however, that the wells have so far responded to all demands made upon them. Many hundreds of animals have been watered from a single well, and in several cases towns of two or three thousand inhabitants derive their supply for all purposes from a single well.

The volume of the springs is as good an index of the amount of sheet water in the rocks as the capacity of the wells, since the springs are formed by the erosion of valleys cutting down to the water-bearing beds. In a few cases the capacity of these springs has been demonstrated. The garrison of Fort Robinson, in Dawes County, is supplied from a single spring, from 50,000 to 60,000 gallons per day being required. The pump runs only a few hours each day to raise this amount, and when it is running at ordinary speed it does not seem to raise one-half the flow of the spring. Considering that the duty of water is fully twice as great in Nebraska as in a region completely arid, it is safe to say that this spring would irrigate 100 acres of land without storage, or 500 acres if the flow during the non-irrigating season were saved by storage. Many similar springs exist in the same region. Their relation to the sheet water which is tapped by the wells on the table-land is shown in Fig. 4. In this case the erosion has extended below the sheet water, and the springs appear on the slopes, and at the heads of cañons, at a considerable elevation above the streams. In other cases the erosion just reaches the top of the water-bearing stratum, and springs boil up from the bottom of the river, as rudely illustrated in Fig. 5. Fine examples of this are seen in Victoria Creek at New Helena, Custer County, and in the North Loup River, where the "Big Spring" rises in the channel, in section 34, township 24, range 24, in Blaine County. The constant volume of the Loup Rivers in spite of drought or down-pouring rains, neither of which cause more than a few inches less or more water, is accounted for by the existence of such springs. These springs in turn demonstrate the strength and extent of the under-flow. These concealed waters constitute an unsuspected source of wealth throughout the whole region of the Great Plains.

(4) THE SANDS AND GRAVELS OF THE PLEISTOCENE.

Copious springs flow from sands or gravels in the glacial drift in many counties of eastern Nebraska. In Holt County, just on the border line between the glacial drift and the lake sediments of the Tertiary, the silted-up valley of the Elkhorn River, including its tributaries from the southwest, presents such alternations of sands, gravels, and clays, with small elevated lakes and absorbent sand-hills for storage reservoirs (see Fig. 6), as to create a group of artesian wells of great interest and of considerable economic importance. About forty wells have been put down, the depth ranging from 40 to 185 feet, in a belt of country 30 miles long running obliquely across the southern part of Holt into Wheeler County. Pressure and volume are both only moderate,

the strongest wells, which are also the deepest, yielding 12½ gallons per minute. The whole group of wells would irrigate 1,000 acres of land if the water were stored during the non-irrigating season. Land of excellent quality lies convenient to receive the water. What it needs first of all, however, is drainage rather than irrigation. The whole valley is water-logged and swampy. Inasmuch as the rain-fall is not always sufficient or seasonable and the ground water is a detriment if allowed to stagnate in the soil, a combined system of irrigation and drainage is required for the complete amelioration of this very interesting region. Whenever such a system is inaugurated the value of the flowing wells will be more fully realized. The drainage ditches will also be irrigating ditches for the lands below, and the whole valley will be enriched and permanent fertility insured.

(5) THE UNDERFLOW OF THE RIVERS.

The visible Platte River is a conspicuous phenomenon, but the invisible Platte, which is buried from sight in the sands and gravels, is probably the larger river of the two. Certainly it excels the visible river in the interest it awakens as an impresssive physical fact, and its economic importance is equal to its scientific interest. The same is true of the Republican River, and nearly the same of the Big Blue. The Niobrara, in that part of its course where it attains considerable volume, flows in a rocky bed, and nearly its whole volume is in sight. But the other large rivers flow in channels excavated in soft material and are choked with their own silt to such an extent that a large part of the water percolates through the silt in the channel, or among the sands beneath the alluvial bottom lands, or spreads even more widely, entering the porous beds far beyond their immediate valleys.

The large towns in the valley of the Platte obtain their supply from the underflow filtered through sand and gravel, thus becoming as excellent in quality as it is practically inexhaustible in quantity. At Fremont fifty "points" driven within a small area, but to different depths ranging from 50 to 90 feet, furnish abundant water to the whole city. The water lies in a bed of sand and gravel 45 feet thick beneath 10 feet of tenacious clay, which serves both to exclude surface water and to confine the underflow, so that it rises nearly to the surface. As a test of the capacity of this plant 2,300,000 gallons have been pumped in twenty-four hours. The ordinary demand is much less.

SUMMARY AND CONCLUSIONS.

(1) The rain-fall of Nebraska, which is the chief source of moisture, is re-enforced by a copious underflow, which feeds the springs and rivers, and promises to yield, upon further investigation, results of great scientific and economic importance.

(2) The geological structure of Nebraska is favorable to the accumulation and economic use of artesian waters. The whole series of sedimentary rocks, Carboniferous, Cretaceous, and Tertiary, is bent into a broad synclinal and tilted away from the mountains. The porous beds alternate with impervious beds. The water entering these porous rocks at a high level flows along the dip and acquires the pressure necessary to raise it to the surface at many points in the State.

(3) The known artesian basin of the Cretaceous in northern Nebraska gives encouragement to further investigation and experiment with a view to determine its extent and value.

(4) The large Tertiary basin of western Nebraska contains in its porous beds sheet water in strong volume and with considerable pressure at several distinct levels. It is likely to yield flowing wells in some localities, and, at all events, will prove a valuable resource by the aid of machinery for raising the water.

(5) The flowing wells and springs in the superficial beds of the Pleistocene are also worthy of notice.

(6) The chief reliance for irrigation in Nebraska is the rivers. Whatever may be the unsuspected value of the subterranean waters, they should be regarded only as supplementary to the visible supply in the streams. Any future investigation should in my opinion cover the whole subject of irrigation, whether the supply of water is to come from visible streams or from the underflow.

(7) The rain-fall would be sufficient for successful agriculture in all parts of Nebraska if it could be relied upon to come in season. But owing to its occasionally spasmodic character irrigation is needed to insure *certainty* and *abundance* of agricultural products. With sufficient moisture the soil is highly fertile.

(8) Extensive irrigations continued for a series of years and the growth of trees would tend to mitigate the violence of storms, to prevent destructive hail, and to equalize and distribute precipitations, so that crops might be produced with certainty each year.

(9) The cost of producing a change so widely beneficial ought not, it seems to me, to fall entirely upon individuals.

REPORT OF P. H. VAN DIEST, C. E., ON THE GEOLOGICAL CONDITIONS OF ARTESIAN BASINS IN EASTERN COLORADO AND NEW MEXICO.

DESCRIPTION OF THE DIFFERENT STRATA OCCURRING IN EASTERN COLORADO AND NEW MEXICO, WITH SPECIAL VIEW AS TO THEIR PERMEABLE OR NON-PERMEABLE CHARACTER.

The representatives of the great geological divisions in the area named are the Archæan, the Carboniferous, the Trias, the Jura, the Cretaceous, the Tertiary, and the Quaternary.

The Silurian rests only at a few places and for little extent upon the Archæan, near Glen Eyrie, west of Manitou, near Turkey Creek, and northwest of Cañon City. The formation is represented as coarse sandstones, covered by arenaceous limestone and capped by yellow-gray limestone.

The first appearance of the Carboniferous in Colorado as resting immediately upon the Archæan is at Perry Park. Thence from the head of Huerfano River the Carboniferous rests upon the Archæan to the south boundary of Colorado. In New Mexico, the formation appears again westerly of the road from Mora to Las Vegas, where it increases in thickness and importance; thence in a narrow belt from the intersection with the New Mexico base line southwards to the Texas boundary, where it appears to gain greater development.

In Colorado the Carboniferous appears as reddish and gray sandstones with intercalated beds of clay of varied thickness, sometimes maroon or deep purplish-brown sandstones, quartzites, and conglomerates and occasionally limestones with chert. These strata reach in places near the south boundary of Colorado a thickness of 6,000 feet. In New Mexico the thickness is not much over 3,000 feet, of which 400 feet are limestones.

The Trias rests immediately upon the Archæan in all Northeastern Colorado. It has there a dip ranging between 30° to 40° to the east. Below Perry Park it is missing as a regular outcrop, except for a short distance, resting upon the Silurian, as at Turkey Creek, or upon the Carboniferous, as at Manitou.

From Albuquerque southerly to the south boundary of New Mexico the Trias gets an important development, resting without interruption on the Carboniferous. Dipping there to the east its strata soon become nearly level and occur as such in the Pecos Valley; also more extensively south of the Canadian to the Staked Plains, only interrupted by isolated mesas of Cretaceous age, which have withstood erosion.

The Trias is generally designated as the red beds. The lower group has in Northern Colorado a variable thickness approximating 1,500 feet, and is composed of massive beds of red and pinkish sandstones and conglomerates, with very little argillaceous matter, capped by a bed

of white quartzose sandstone. The upper group averaging 600 feet in thickness is composed of fine-grained, brick-red sandstone and shales, with thin intercalations of limestone and variegated clays, with layers of gypsum, capped with a thin bed of pink sandstone.

The Jura follows the Trias rather persistently. It consists of a bed of drab, marly clays 130 feet thick, covered by sandstones and clays to a thickness of 60 feet.

The Cretaceous strata crop out everywhere along the foot-hills from Northern Colorado to the south of New Mexico and all over the plains, where it is not concealed by Tertiary and Quarternary deposits. The formation is divided into the Dakota, the Colorado, the Montana, and the Laramie. Its basal member, the Dakota, forms prominent hog-backs standing up in sharp ridges. In Colorado it is essentially a sandstone 200 to 300 feet in thickness. The lower bed is a conglomerate of quartz pebbles, jasper, and chert, with a siliceous cement. In New Mexico the Dakota gets more prominence and swells to a thickness of 1,700 feet, with a bed of shales and impure limestone of 600 feet thickness between the sandstone beds, one of 350 feet thick underneath and one of 750 feet on top. The Dakota is in Northern Colorado east of the mountains interrupted for a mile north of Golden, where the Laramie sandstone approaches to within a tenth of a mile of the Archæan, thence south of the divide between the Platte and Arkansas for several miles westerly of Palmer Lake, where the Laramie and the Monument Creek beds rest upon the Archæan, and again for a short distance south of Colorado Springs, near Cheyenne Mountain, where the Colorado Cretaceous rests upon the Archæan.

The Colorado overlies the Dakota with a bed, very constant in thickness in Colorado and New Mexico, of 400 or 500 feet of black clays—the Fort Benton division—and a bed of 300 feet of white limestone and silici-calcareous shales—the Niobrara division.

The Montana varies largely in thickness. Its maximum is over 8,000 feet. In general the strata thin out towards the plains, as the borings at Fort Lyon and Cheyenne Wells have demonstrated. In New Mexico the Montana appears to have less thickness than at some places in Colorado. The formation is to within a few hundred feet of the top a series of drab shaly clays only once interrupted by a band of quartzose sandstone, which in the borings at Greeley, and probably also at Raton, was struck and furnished the water rising in those wells. The top layers are more arenaceous, although they maintain a shaly character.

The Laramie, a brackish water sedimentation, follows the marine or middle Cretaceous as a closing member. It has undoubtedly its greatest thickness of several thousand feet in Wyoming. In northeastern Colorado its thickness does not exceed 750 feet. In southeastern Colorado and northeastern New Mexico its thickness is about 1,800 feet. The Laramie has at its base a heavy-bedded sandstone generally 200 feet thick, thence drab, white, red, or green clays alternating with layers of sandstone and coal, and at its top, in the southern field, sandstones. The extent of the Laramie east of Denver is approximately limited by the 5,000 contour line on the map, because beyond that line easterly the Montana clays and shales occur.

In wells and in arroyos denuded of loess, southwest of Colorado Springs, a patch appears near Cañon City. Thence south of the Huerfano it gets again a large extent, which has its southern limit at the Cimarron Creek, in New Mexico. South of that point it appears only in small patches in New Mexico, as for instance near Galisteo.

Unconformably upon the Laramie rest, near and south of Denver,

several beds of the Miocene Tertiary. The lowest bed is named by Mr. Eldridge the Arapaho. It varies in thickness between 600 and 1,200 feet. It has a basal member of conglomerate or gritty sandstone, according to its distance from the foot hills, with overlying gray argillaceous or arenaceous shales.

Above these are strata of alternating conglomerates, grits, sandstones, sandy clays, and clays, named by Mr. Cross the Denver beds. They have a maximum thickness of 1,400 feet. In the city of Denver the thickness is not much more than 30 feet, as borings have shown. All these strata are of andesitic nature. Above the Denver beds are found the Monument Creek beds, which get a great extent and a thickness of about 1,500 feet near Colorado Springs. Their eastern limit is on the map coincident with the 6,000 contour line.

In the Huerfano basin near Badito, Mr. R. C. Hills discovered exposures of Eocene beds of a thickness of nearly 7,000 feet, composed of sandy clays, marls, greenish sand, soft sandstones, and conglomerates with occasional beds of yellow clay. Exposures of limited extent of Pliocene age occur above these Eocene beds near Badito, consisting of coarse conglomerates and sandstones. In northeastern Colorado, Pliocene sandstones occur between gentle plications resting upon Montana beds. The buttes north and south of Sterling are such sandstones. Near to the north boundary of Colorado whitish marls occur. The tablelands north and south of the North Fork of the Republican are composed of grits, containing siliceous, calcedonian, and andesitic pebbles. In eastern New Mexico the Galisteo group of Miocene age appears from Lamy Junction to Ortiz, and consists of a dark-gray breccia, covered by soft, light-gray sandstones, together 200 feet thick. The Pliocene Santa Fé marls are marly limestones and clays, hardly 20 feet thick.

The Quaternary covers a large portion of east Colorado. It appears, where not removed by recent erosions, as a mantle of fine earth varying in thickness from a few feet near the foot-hills to over 200 feet thick near the Kansas line. In Nebraska it appears to become nearly 300 feet thick. In general this material resembles the loess of the Mississippi, the Rhine, and the Wéi in northern China, where it has, as described by von Richthofen, stupendous extent and thickness. It is here classed as Quaternary, but it remains yet a matter for settlement whether it shall be so classed or more correctly with the Pliocene Tertiary. The color near the surface is an ashlike brown which becomes gradually lighter until it is nearly white near the State line. The lower portions are often stained with calcareous matter, and nearest to the foot-hills large amounts of rounded stones occur in the basal layers. In the eastern portions of the State the fine silt brought down from surrounding slopes form over small areas a sufficiently impervious layer to hold water, thus creating the many ponds found near the Kansas and Nebraska line. They are shown on the accompanying maps with the adopted signs for such water-holes.

This loess-like formation is in general very porous and absorbs water readily.

Æolian sand hills are observed at different places in the most northeastern part of Colorado, east of the South Platte River. Also near the southeastern border of the State are many shifting sand hills.

In New Mexico, west and east of the Pecos, the surface appears to be covered with a similar mantle of quaternary, or, perhaps, late tertiary, deposits, which on the staked plains has considerable thickness.

The foregoing will have conveyed the impression that the surface of Eastern Colorado and a large portion of Eastern New Mexico is of a

predominant sandy and pervious nature. This is not only the case on the plains, but also in the foot-hills, with the exception of the outcrops of the Middle Cretaceous. The pervious layers in the foot-hills are in general so steeply upturned that they cover but a limited collecting area, consequently they cannot carry to the subsoil great volumes to be tapped by artesian wells. The confining beds are all that can be desired as to imperviousness and resistance of pressure in formations below the Laramie, but, with a few exceptions, they carry the water strata confined between them too far below the surface of the plains in Colorado to be available for agricultural purposes. That is certainly the case with the water-layers confined in the Dakota and Trias, unless in limited localities these should yield strong flows of artesian water, as is true in a large area of the two Dakotas, where the Dakota sandstone is the reservoir source of large wells.

The Montana beds which, in eastern Colorado, east of the 5,000 contour line, are found immediately under the loess are nearly all impervious, and have a great thickness above the thin layers of sandstone occurring between the shales. These sandy layers show rarely in the foothills, except in natural and artificial cuts, and they can collect and hold only an insufficient supply of water. An example of a very limited supply in these Montana beds are the wells at Greeley. When one well was pumped all the others stopped their flow.

The clays of the Laramie and the Tertiary, where they show upturned edges, appear to be very variable in thickness and character. These confining beds are at many places leaking layers, as some borings have shown, and they are sometimes covered by a semi-pervious saturated strata, which often acts as a confining agent and, although far away from the collecting upturned edge, aid in giving pressure and volume to the well.

DESCRIPTION OF ARTESIAN BASINS AND SEMI-BASINS, THEIR GEOGRAPHIC POSITION AND EXTENT.

The knowledge of the extent and direction of anticlinal axes of plications and undulations of the strata is essential to the study and the outlining of artesian basins. On the accompanying maps are placed such anticlinal axes as are known to exist with certainty.

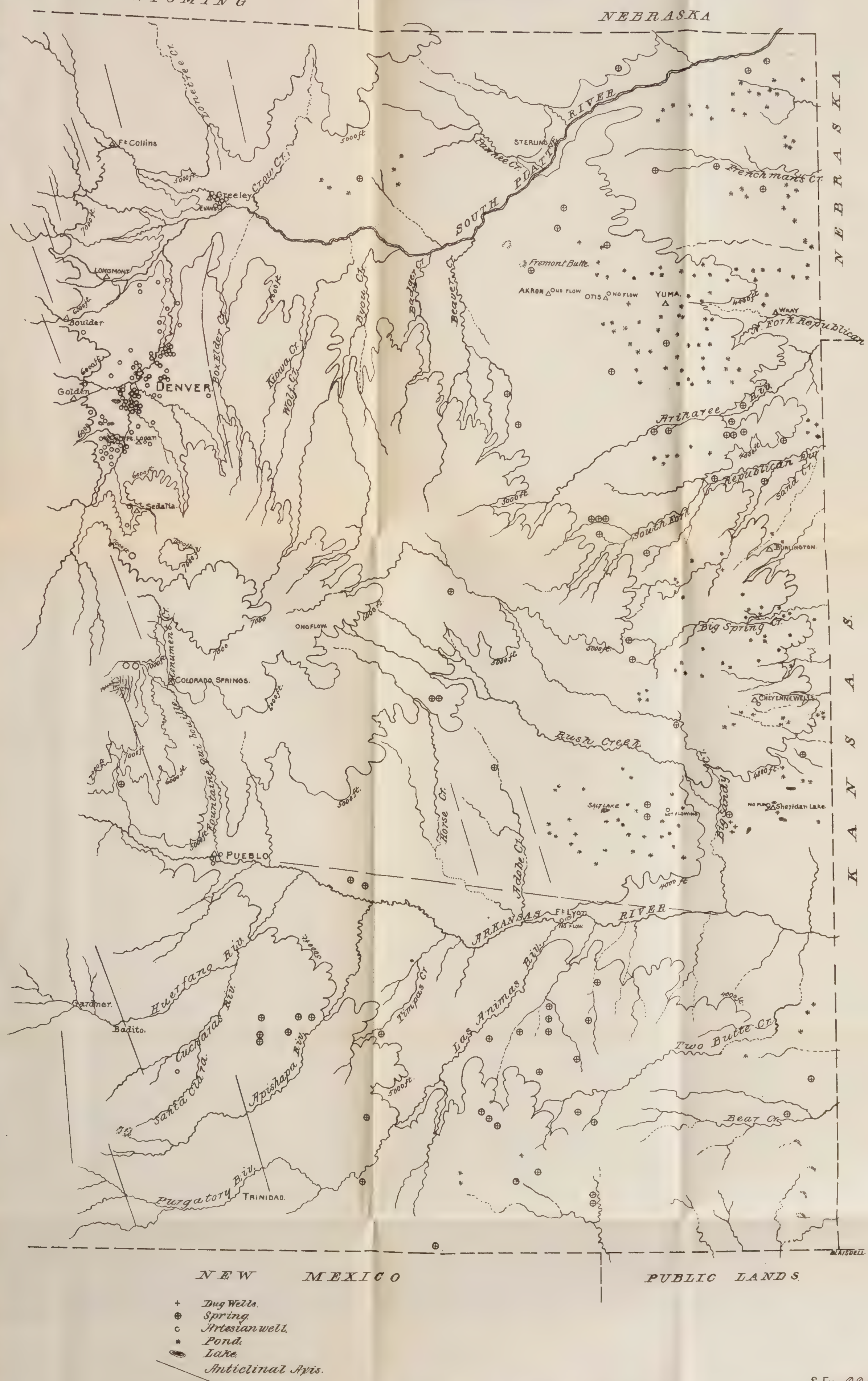
Interdependency of topography and geology is in eastern Colorado and New Mexico very marked. It is therefore to be regretted that a contour line map of eastern New Mexico does not exist, because such a map would have aided materially in delineating the bounds and the extent of basins with more accuracy than could be done in this report. Still more it is to be regretted that the time given for preparing this report was too short to allow the visiting of places indicative of subterranean basins. Consequently the following description of basins is, with the exception of the Denver basin, very incomplete, merely suggestive for further investigations as to the necessary requisites of artesian basins.

Near the north boundary of Colorado, principally in the vicinity of the Big and Little Thompson creeks, are observed several anticlinal axes, which are the consequence of the "en echelon" structure of the strata. East of Greeley occurs a gentle anticlinal axis. Between these axes a basin of some extent may be expected, and the upturned edges at one side at least being considerably higher than the basin, a sufficient fountain head may exist.

Map of *Eastern Colorado.*

showing Springs, Lakes, Ponds, Artesian Wells and Drainage.

Scale 16 Miles to 1 inch.



The Cache La Poudre Creek follows such a trough with a northwest and southeast fold, which extends to and beyond Greeley.

Near Fort Collins the Trias lies at not too great a depth below the surface, and good water may there be obtained out of the generally soft and porous sandstones of that formation. In Greeley wells have to go considerably deeper to find these strata than the depth attained in the seven wells bored there, and the one at Evans to a uniform depth of 1,160 feet, obtaining water from a 10-foot seam of soft sandstone of Cretaceous age. Water is scarce in the lower horizons of the Cretaceous formation and laden with soluble salts and often contaminated with oil. North of Greeley, along the valley of the Lone Tree Creek, at less depth, purer water may be expected out of the Laramie, with probably sufficient pressure to rise to the surface. Gentle folds exist undoubtedly east of Greeley, of which the axes follow the Bijou, the Beaver, the Pawnee, etc., but there the Middle Cretaceous is very thick, as borings at Otis have demonstrated, and if water may be found at great depth it is not likely to have pressure enough to rise to the surface. If water there is reached by deep borings it will not have the volume that is found everywhere in that region in the pervious strata lying at the base of the loess-like formation on top of an impervious floor of Montana shales.

The Tertiary beds which occur in that region are practically horizontal, and thus miss one of the requisites of pressure. The water that sinks in these hills appears on the surface as springs, for instance those near Fremont Butte, or sinks in cracks to deeper strata. Longmont and surrounding country appear to be in the same artesian condition as Greeley.

The Platte valley from Sedalia to Platteville is, in eastern Colorado, in the most favorable condition to secure artesian water under pressure. There, between the foothills and the anticlinal axis directly west of the Box Elder Creek, is formed a basin, which on the south is limited by elevated country. It is not an ideal basin, closed in on all sides by upturned strata, but of a horseshoe shape, its curve extending from the base of the Laramie formation along the south banks of the St. Vrain and Boulder creeks towards Golden, southerly to a mile and a half east of Morrison; thence south and southeasterly to Sedalia; thence northeasterly, crossing Coal Creek towards the Box Elder. This line connects points 5,650 feet above sea level, and is from 300 to 400 feet above Denver. The greatest width of the Denver basin is nearly 30 miles, and its length about 55 miles. In the following chapter this basin, its capacity and peculiarities, will be more fully described.

South of the divide, between the Platte and the Arkansas, is a narrow elongated basin, in a fold of which the Monument Creek is the axis. The creek runs over Laramie strata, which at one side at least has upturned edges, high enough above the valley—from 400 to 600 feet—to insure pressure. This basin extends to Colorado Springs, which point, however, is located below the Laramie outcrop. There artesian water having some pressure must be expected from strata below the Colorado group, 700 to 800 feet below the surface. Following the Fountain qui Bouille to Pueblo, the depth to a water-bearing strata will increase and pressure decrease.

The Pueblo basin follows the Upper Arkansas. In Pueblo borings have, at depth of 1,400 feet, penetrated the Jura, obtaining an impure water, under good pressure, out of one of the upper sandstone layers of that formation.

East and a little north of Pueblo a gentle anticlinal axis has been observed coursing eastward to the State lines. Gentle undulations, running north and south, branch at intervals from this anticline. Deep borings between those folds may reach water in the Trias, but it is doubtful if there will be sufficient pressure to reach the surface. The wells bored at Cheyenne Wells to 1,770 feet depth were not successful, and the report of Messrs. C. A. White and S. Aughey on the Fort Lyon well is not encouraging to expect much benefit for agricultural purposes of wells in that region.

Gardner, on the Muddy Creek, a branch of the Upper Huerfano, is the center of a small Tertiary basin occupying a syncline between the Wet Mountain and the Sangre de Cristo anticlinal axes.

East of the Wet Mountain anticline the Cretaceous gets great development, and the chances to find there a good artesian supply again become doubtful.

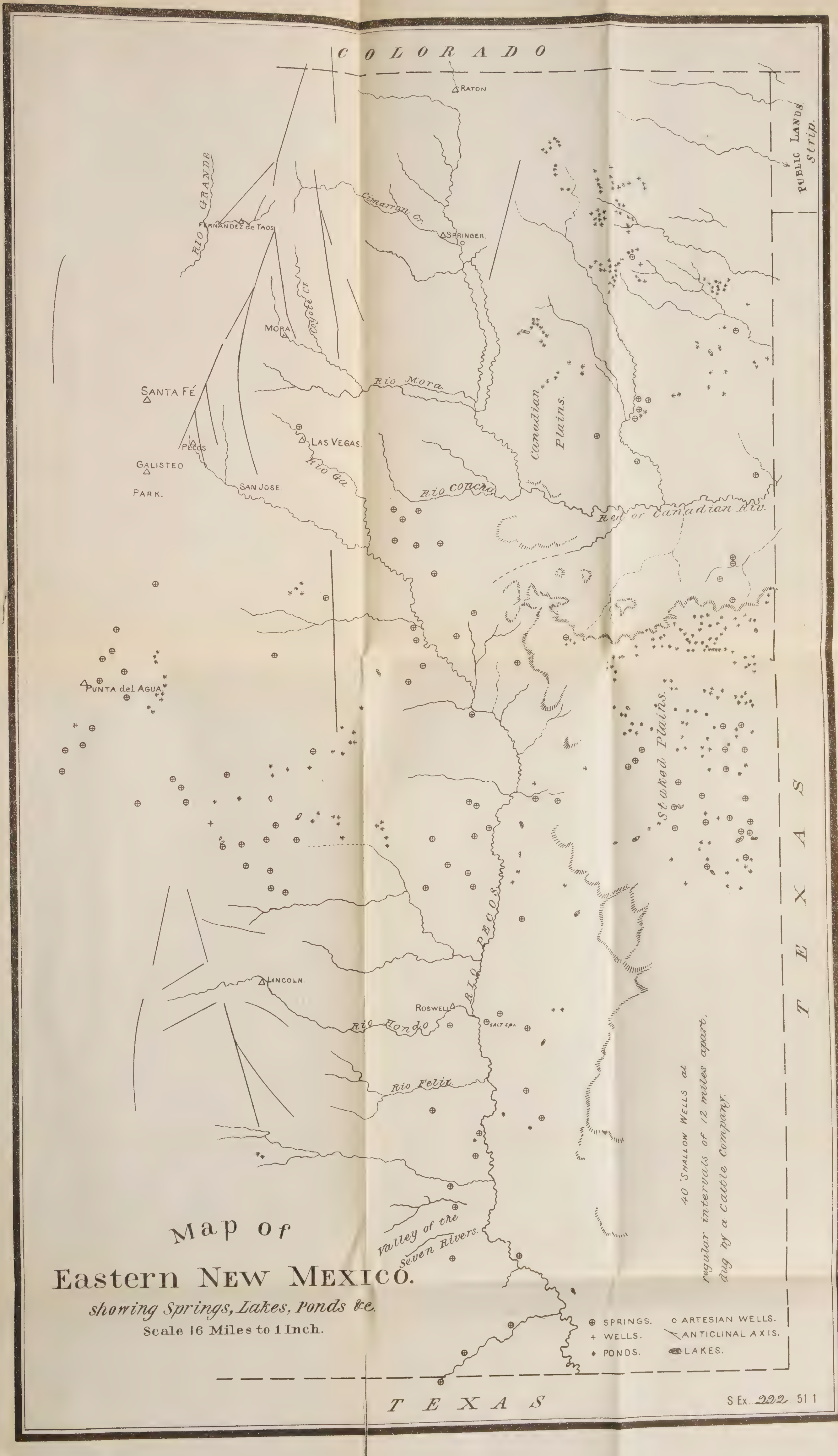
The chances for locating artesian basins, at least semi-artesian basins, are in eastern New Mexico perhaps a little more favorable than in eastern Colorado. Several anticlinal axes running from the mountain ranges towards the plain, divide the country near the foot-hills in troughs which may contain water under sufficient pressure to rise to the surface. The supply can be expected out of the Dakota sandstones, which are more porous and more divided by confining clay beds than its representative in eastern Colorado. The Trias also lies at many places not so deep under the surface as in eastern Colorado; and in other places, as Las Vegas, Pecos, La Cuera, good water can be expected out of the Carboniferous sandstones.

Small basins can be expected along the Cayotte Creek, also one below La Cuera, along the Mora Creek, to the cañon of the Mora. A possibility exists that farther east, along the Ute Creek Valley, although with feeble pressure, water may be obtained. On the Canadian plains basaltic dikes cut off the drainage too much to expect a sufficient supply in wells.

Las Vegas is situated in a basin that has upturned edges, westerly, at considerable height above the valley A well bored in Las Vegas reached at 1,600 feet depth a flow that rose to the surface. In the Upper Pecos Valley, from Pecos to San José, water can be expected to rise to the surface. The valley lies in a syncline between two anticlinal axes. The formation is Carboniferous, and on each side is the Archaean. The fine park south from Galisteo might be supplied by artesian water, for it would receive the drainage from the hills stretching eastward, in which the rocks dip towards the park. South of this park, towards Punta del Agua, a basin may be found, hemmed in by outcrops, dipping on one side to southeast and on the other to northwest. The upper valley of the Cienega del Macha follows the axis of a syncline, the fountain-head being formed by upturned strata on the west and south, and dipping northeasterly. North of the Rio Hondo a small basin may exist, which is bounded on the west by hills which show upturned Trias beds.

At Lincoln, in the Fort Stanton military reservation, water may be found in a patch of Carboniferous sandstones between a break in the Archaean.

Although on the west side of the Rocky Mountain Divide, and thus beyond the limit of the artesian investigation, I wish to call the attention to the possibilities of obtaining artesian water in the Taos Valley, Jemez Valley, the Pueblo Laguno, on one of the valleys of the San Jose, and also in the country of which Hillsborough is the center.



Map of Eastern New Mexico.

showing Springs, Lakes, Ponds &c.

Scale 16 Miles to 1 Inch.

S Ex. 222 511

DETAILED STATEMENTS ABOUT THE DENVER BASIN.

The approximate limits of this basin were given in the previous chapter. The east and west borders are well defined. The extent north and south not so well. So it may be that a narrow neck of the trough extends several miles farther south than Sedalia, where the Laramie comes to the surface with a dip north. The basin has a trend from northeast to southwest. On the northwest side the Laramie gets considerable extent. Near Boulder that formation is interrupted by displacement of older strata, as the consequence of faulting in that region.

Southerly the Arapahoe is found over the whole width of the basin, and reaching to a line 5 miles north of Denver, where, near Clear Creek, the Denver beds appear. At that latitude a piece of Laramie wedges between these two Tertiary beds and reaches nearly the right bank of the Platte.

South of Denver City the Denver beds get their largest development, reaching to 13 miles south of the center of the city, where they are overlaid by the younger Monument Creek beds. Near the mouth of Plum Creek these Monument Creek beds are found joining a small western exposure of the Arapahoe beds.

The accompanying section from Golden through Denver to near Box Elder Creek gives an idea of the position of the above-described strata across the basin. Some of the wells situated along this line are represented on this section.

Two sandstone layers are found rather persistently under the city of Denver. These layers bear water of sufficient hydrostatic pressure to insure a regular supply without pumping. They have a depth below the corner of Lawrence and Sixteenth streets of 375 and 600 feet respectively. Other wells located east and at higher points strike these layers so much deeper than the depths already given as is their differences in altitude from that of the initial points named. This indicates that the strata are level under Denver, at probably the deepest part of the basin. Besides these two rather persistent beds several others occur at less and at greater depth, but they are very variable in extent and thickness. Some wells have met six or seven sandstone strata with water under pressure in them above the 375-foot layer; others located at short distance met only one or two or none.

The pressure even from these two generally permanent seams varies greatly. One well reaching these strata will have a pressure of 25 pounds, while another near by, at the same level, will have but half or double that pressure. In some localities, for instance in that part of the city where most of the breweries are located, and again near Argo Park, the flow of each well is about the same, and none appears to have been affected by another. In other localities, for instance near the work of the Denver Water Company, this condition is quite different. One well was sunk to a depth of 590 feet, giving a flow of 95 gallons per minute. When a second well was sunk at a distance of 250 feet the first one was reduced one-third in capacity. A third well near by reduced the flow from the other two, so that the aggregate flow of the three wells is about the same as obtained from the first. In some localities, for instance section 1, township 4 south, range 67 west, the layers found open and giving a good flow at one well are found so tight at a short distance in another well that hardly any water is encountered, and what there is does not rise to the surface.

This is all due to the non-homogeneous character of the sandstones in the Arapahoe beds, and also to the variability in character and thickness of the confining layers in the beds.

In the city of Denver only one well, the court-house well, has attained a depth of 930 feet, and has reached the Laramie formation. It is very likely one of the top sandstone layers, which are often stained with iron and give the water an inky taste. There is hardly any doubt that the basal sandstone of the Laramie lies about 1,500 feet below the city; in other words, the Montana shales will not be reached before a well has obtained that depth. It is also very probable that when this depth is reached a large supply of water can be expected in these thick sandstone layers. These layers are fed by numerous streams and rivulets nearest to the mountains, and crop out at somewhat higher altitude than the Arapahoe and Denver beds, and have consequently a higher fountain head. That soft water can be expected in these basal sandstones of the Laramie is demonstrated by a well in section 12, township 1 south, range 70 west, six miles easterly of Boulder. The last coal seam, 5 feet thick, was struck in that well at a depth of 124 feet, then followed 25 feet clay and 208 feet of sandstone. A good flow of soft water was obtained from this sandstone bed. Some dry coal mines in Boulder County obtain water by drilling through the shale under the coal veins and into sandstone.

It is very difficult to make an estimate of the total quantity of water being supplied by the artesian wells in the Denver basin. The counting together of the stated capacity of the existing wells would give a very questionable aggregate. The wells are generally measured only once, directly after completion, when causes of decrease in flow had not any effect on the well. These causes are:

First. The filling and clogging up with sand of the often poor casing.

Second. The filling of the pores of the strata with silt, brought along with the water, which, relieved of pressure, is rushing to the well from all directions.

Third. The tapping of the same water-bearing stratum by later-bored wells, often more advantageously located.

Most of the wells, in the country especially, are not flowing continually.

The sum of the stated capacities may reach 4,200 gallons per minute, but the total quantity supplied can not be more than half, or 282 cubic feet per minute.

Very little of this water is used for irrigation. Some instances are reported where artesian water in the Denver basin is used for irrigating fruit trees and vegetables. Manufacturers, breweries, laundries, and hotels use the water nearly exclusively, and consume the greatest portion of the water which rises in the Denver basin to the surface. If most of the wells were not located in and near Denver, and if it happened that there was no city of Denver, so that all the water rising in all the wells to the surface could be applied for irrigation, then the above-estimated amount would be sufficient for irrigating 420 acres, counting on the average need of 1 cubic foot per minute for every 1½ acres.

If, during the time in which no irrigation is needed, the supply of the wells could be stored in reservoirs, and if deep borings drew on lower water-bearing strata, the total quantity of supply for irrigation could be probably doubled, but even under such favorable circumstances the artesian supply could irrigate only the one six-hundredth part of the area of the basin, which is very near 1,000 square miles.

It is almost a certainty that none of the other basins in eastern Colorado and also in eastern New Mexico can produce a larger artesian supply than the Denver basin. What is known of these basins places them, as to the character of water-bearing strata, collecting area, and

quality of the water, in a less favorable condition than the Denver basin.

West of the Rocky Mountains is located in Colorado a basin generally known as the San Luis Valley basin, where the artesian wells are likely to become an aiding factor in the irrigation problem of that region.

It is said that there are wells which reach at a relatively shallow depth a water-bearing stratum which gives the well a flow of nearly 1,000 gallons per minute. This San Luis Park appears formerly to have been an extensive lake, formed by Tertiary basaltic flows, damming off the Rio Grande and tributaries at a point some 15 miles south of the Colorado boundary line. Similarly formed basins, although of smaller extent, may exist in New Mexico.

SUBTERRANEAN FLOWS WITHOUT HYDROSTATIC PRESSURE.

By subterranean flows without hydrostatic pressure is meant the accumulation of water in the lower strata of the Quaternary or late Tertiary deposits, which cover to such a large extent the plains of eastern Colorado, and also much of the plains of New Mexico. It is that portion of the water from the surface that is in excess of the absorbing powers of the sandy surface over which it flows. Some of the water that sinks in this loëss-like material comes in the form of springs at favorable spots to the surface, but this, at least in eastern Colorado, is a small portion of what sinks to a depth of from 10 to 250 feet under the prairie to find its way to rivers east of the State. This amount thus subtracted from the soil is very great, and far in excess of what is collected at the pervious rims of artesian basins.

It is stated on good authority that at Platteville a stream of water flows audibly 30 feet below the surface in a northwesterly direction, and where this stream is intercepted by dug wells the water rises to within 5 feet of the surface.

The South Platte, in Weld and Morgan Counties, swells suddenly at several points, and increases in volume without visible side flows. Well-diggers state that everywhere in northeastern Colorado water is found at varying depths, which by pumping appears to be almost inexhaustible. A certain Mr. Williams, a well-digger, says that he never struck a point in eastern Colorado where he could not find water, while he did fail in Nebraska and Kansas. He thinks that in these States the underground water runs in veins, while in Colorado it is in sheets.

The depth of this underground water differs with the thickness of the loëss-like formation, with the sands or gravels beneath, reposing on an impervious floor of shales and clay. In northeastern Colorado it is thickest, reaching in places a thickness of 250 feet, and generally deposited on Montana shales. Along the Arkansas, in Bent and Prowers Counties, the loëss reposes generally on Fort Benton shales, and is from 40 to 100 feet thick. In Baca County, in the southeastern corner of Colorado, the Quaternary deposits are less thick, from 20 to 75 feet.

In New Mexico, under ground, water is reported to be found at depth varying from 10 to 50 feet below the surface, over enormous areas, in inexhaustible quantities.

Eastern Colorado has a good supply of springs. Many of these springs are not affected by dry or wet seasons, and have a constant flow. The water of some of them runs only a short distance, to sink again in the sandy alluvia.

It is difficult to estimate the capacity of these springs. Some springs in New Mexico discharge enormous volumes of water. North Spring River, a tributary of the Rio Hondo, is, at 60 feet from the spring which creates the river, 40 feet wide. Springs in the San Luis Park, Colorado, have been measured. It is said that one spring there delivers 12,000 gallons per minute. It demonstrates that a large portion of the rain-fall disappears in the porous soil that covers the plains. Usually once a year only the rains are so copious that arroyos are formed, and that the drainage beds carry water for a short period,. The creeks and gulches are nearly always dry. The greatest part of the yearly rain-fall sinks quickly in the soil, hardly leaving time for evaporation to return a portion to the clouds and to the scanty vegetation to absorb another portion. In the winter more will evaporate of the snow-fall than of rain-fall in the summer, but a great deal of the snow sinks in the ground, often so rapidly that the process can be watched.

It is not an exaggerated estimate that half of the rain-fall in eastern Colorado, and probably also in eastern New Mexico, sinks into the ground. In eastern Colorado this will not be less than 5 inches over an area of 32,000 square miles, which is equal to 784,080 cubic feet of water disappearing over that area per minute. If this amount could be redeemed from the subsoil it would be sufficient for the irrigation of 1,200,000 acres, or one-seventeenth part of the above named area. A considerable amount of this subterranean water could be utilized by pumping it to the surface as is here and there done, but until now this is being done only on a very limited scale. The air currents generally present on the plains could be made to move pumps to raise the water where desired. Wind is a cheap and powerful motor. It is not always at command, but many of the dry ponds on the prairies could be changed into reservoirs to hold the surplus water pumped during windy days.

The plains of eastern Colorado and New Mexico could be dotted over with wind-mills to keep the water on the land, as the "polders" in Holland are dotted with wind-mills to keep the water from the land. A little calculation would show that the outlay for digging a well and putting up a wind-mill is not greater than the cost of boring an artesian well to a depth of 800 and 1,000 feet.

An artesian well even within the limits of a recognized basin is not always successful, and to get sufficient water often the well, although flowing, must be pumped. It is the general impression that an artesian well needs no attention, that it is a boon for always; but this is not the case. It requires often costly cleaning of clogged-up sand and renewing of packing and casing to maintain a constant flow.

DISCUSSION OF THE QUESTION AS TO WHETHER WATER FROM ARTESIAN WELLS AND UNDERGROUND FLOWS MAY IN THE FUTURE BE A LARGE OR UNIMPORTANT FACTOR IN THE WORK OF IRRIGATION.

The artesian flows are means of transfer of water from humid regions to more arid tracts.

The advantages of such transfer over transfer of water in irrigating ditches are: That it costs nothing; that there is no loss by evaporation and seepage, and that the supply is uniform and practically independent of a dry season. The hydrostatic pressure forces the supply to a point where the water is needed, provided a communication is made between the underground flow and the surface.

If the depth of the water supply is not too great, the cost of boring

will in many cases be less than the cost of bringing the water by long ditches to the land.

The limit of depth to which boring for water can advantageously be undertaken is largely dependent on the amount of supply that can be obtained and on the kind of crop that can be raised on the land to irrigate. It can pay to bore to a considerable depth for irrigation of fruit trees and garden truck when the flow is small, while for raising wheat it may not pay to bore at a moderate depth even when the flow is large.

The utilization of artesian flows has a great disadvantage in the many requisites of a flowing artesian well. Only at a few places in eastern Colorado and New Mexico these several conditions are so happily combined that artesian wells are cheaper means of irrigation than by laterals from ditches. Another drawback is that artesian wells must necessarily be bored at lower levels than the collecting area, and consequently are not beneficial at points higher located than can be reached by ditches. On these grounds the artesian well can never become a very important factor in irrigation in Colorado and New Mexico, but it may be in many places a great benefit when the water supply from other sources is small.

In eastern Colorado, where the climatic conditions and the soil limit agriculture to cereals, an artesian well does not give a sufficient supply for so large a tract as such a culture requires to become profitable. It is, however, an excellent auxiliary to the efficacy of the ditch. The farmer who has an artesian well in addition to his ditch lateral has an advantage over his neighbor similar to the advantage in the time before the opening of the Suez Canal of the Indian merchantman with auxiliary steam-power over the sailing vessel for weeks becalmed within the tropics.

The utilization of underground flows without hydrostatic pressure is not so limited as the utilization of true artesian flows. The collecting area of this kind of subterranean flows is in eastern Colorado and New Mexico vastly greater than of artesian flows; they occur at less depth, and although they have but feeble or no pressure and must be raised artificially to the surface they can be forced in great volumes to points higher than ditches from neighboring streams could reach. The possibilities of bringing productiveness to a large area of arid land by the utilization of these underground flows are great. They may become in the future very important factors in the work of irrigation, and deserve a closer and more detailed investigation than the very limited time of the present investigation allowed to devote to this problem.

REPORT OF PROFESSOR E. T. DUMBLE, STATE GEOLOGIST OF TEXAS, ON THE EXISTENCE OF ARTESIAN WATERS WEST OF NINETY-SEVENTH MERIDIAN, ETC.

In answer to your request of May 2, 1890, for a statement as to the existing artesian water conditions of that portion of Texas west of the ninety-seventh meridian and north of San Antonio, I take pleasure in furnishing you the results of my investigations in this direction.

The part of the State covered by your request includes four topographic divisions. First, in its eastern part we find a small area of the Gulf coast formation followed by the plateau of Grand Prairie. From the northern and western scarp of this plateau the Central Basin region stretches away west to the Gaudaloupe Mountains, beyond which we find the mountain region of Trans-Pecos, Texas. The approximate boundaries and extent of these regions are shown upon the map accompanying this report. The small exposure of the Gulf coast formation in the southeast comprises beds belonging to the Upper Cretaceous and Lower and Middle Tertiary, but they are so limited in area that, as regards this report, they do not need description.

The Grand Prairie plateau is a marked topographic feature of the State. Beginning at Red River it extends in a gradually widening belt to the south until its western border meets the Colorado in Lampasas County, from which point it is contracted rapidly until it finds its narrowest exposure in crossing the river in Travis County, north of Austin. From this point west it broadens rapidly, until it is merged into the mountainous Trans-Pecos region. Its height above the country on either side is variable. On its eastern border, from Red River to the Brazos, there is not that abruptness of separation which distinguishes it at other places from the upper and lower formations.

The western and northern edge of the Grand Prairie is, generally speaking, topographically higher than the eastern and the southern, and the dip of the beds is very gentle towards the southeast. The rock formation of this plateau belongs to the Lower Cretaceous series, and consists of a great thickness of limestones and chalks, magnesian, arenaceous and even argillaceous in places, which is underlaid by a bed of sands, the outcrop of which is shown on the accompanying map by horizontal hachures. The boundaries of this bed between Red River and the Colorado are as accurate as the scale of this map will allow, but west of that point the probable location is all that is attempted to be shown.

This bed, the Trinity or upper cross-timber sands, is the base of the lower Cretaceous system and is the great water-bearing bed east and south of the central basin. In its many exposures and from the material brought up from it in boring, its composition is shown to be clear white grains of quartz, slightly rounded to much worn, containing a few grains

of red and black chert. It is, for the most part, practically free of soluble mineral matter, and the water derived from it is often of excellent quality.

The favorable conditions for artesian water supply in the district underlaid by this water-bearing bed are fully proved by the great number of existing wells throughout the entire area east of the Trinity sands so far as this report extends. In nearly every county between the ninety-seventh and ninety-eighth meridians and east of this outcrop, artesian water is obtained in wells varying from 200 to 2,000 feet. That it is equally favorable to a similar supply in its southern portion is shown by the line of great springs or natural artesian wells, which find their head in it and stretch from Williamson County southwest by Austin, San Marcos, and New Braunfels towards the Pecos. These prove that artesian conditions exist, and there can be no doubt that wells bored in suitable localities will prove successful.

West of the Grand Prairie plateau we find the central basin region, which is principally occupied by strata of the Paleozoic formations. The eastern and southern border of this area is plainly marked by the scarp of the Grand Prairie. Its western border is not determined further than that in Texas it is terminated by the Guadalupe Mountains in El Paso County. In its topography it shows a gradual elevation towards the west, most usually however in series of steps, which rise one above the other, having the ascent facing toward the southeast and a long gentle slope toward the west, the average rise being less than 8 feet per mile.

At the edge of the Staked Plain, which is a newer formation superimposed upon these, there is an abrupt elevation of from 200 to 300 feet in places and a continued rise toward the west to a height of 3,100 feet at Quito. West of the Pecos the rise is much more rapid, being about 15 feet per mile. The dip of the strata, which on the east is toward the northwest not exceeding 40 feet to the mile, is reversed, that is, it is to the southeast, and brings the edge of the strata to the surface again after crossing the river. In the southeast corner of this region we find the Archæan area of Llano County, around which the upturned edges of the older Paleozoic rocks are exposed at a considerably greater elevation than that of the basin north of them giving the overlying rocks of the basin itself a northward dip. The western extension of this southern border has not been examined.

We find the northern border of our basin in the Wichita Mountains in the Indian Territory, where the edge of the Silurian rocks is again exposed at a higher altitude than the interior portion of our region. This region is, therefore, of a basin form of structure, with the exposed edges of its lower members and the underlying rocks topographically higher on the northern, western, and southern borders than on the east or in the center.

The formations which occupy this basin, if we except some overlying Cretaceous and the plains formation, are almost entirely confined to the Carboniferous and Permian systems. These consist of beds of limestone, sandstone, sands, clays, and shales, with coal, gypsum, and salt as associated deposits. The general dip of all the strata in the eastern portion of the basin is to the northwest, but its elevation along the eastern border is less than in almost any portion of it, consequently there can be little hope of finding artesian water from any catchment area on this side, although some of the strata (the lower sandstone and shales) are well adapted for carrying water and, where suitable topographic conditions exist, do furnish artesian water. An instance of

this is found in the flowing well at Gordon, but such cases are the exception, and not the rule. The same series of sandstone, and shales are exposed on the southeastern border and the flowing wells at and around Trickham and Waldrip find their supply in them. The conditions are very favorable in the valley of the Colorado and some distance north, between the ninety-ninth and one hundredth meridians for similar wells. The rocks of this age are covered by later deposits in the Wichita Mountains, and it is therefore impossible to judge of the possibility of their water-bearing character there. Similar rocks are exposed on the western border of this basin, in the vicinity of Van Horn and farther north, in the Guadalupe Mountains. They are reached by a well 832 feet deep, at Toyah, some 70 miles east of Van Horn. This well has an abundant flow. We have, therefore, in the lower members of the Carboniferous rocks of this basin water-bearing strata, the exposed edges of which on the southeast and west are sufficiently elevated to furnish artesian water to portions of the basins in their immediate vicinity.

We do not know what interruptions to the subterranean flow may exist in the way of dikes or fissures, and therefore the areal extent of the portion favorably situated can not be given until the topography and geology are better known. The quality of the water from every well thus far secured in this basin, which has its origin in this series of rocks, is highly saline, and it is safe to assume from this and from the character of the deposits that no fresh water can be obtained from this source. Therefore, if the supply be general over the entire region it will only be adapted for limited uses. In addition to this, this water-bearing bed can be reached in the greater portion of the region only after passing through the entire series of Permian strata and those of the uppermost Carboniferous, amounting in all to 2,000 or 3,000 feet, or even more in places.

If there be any other hope for an artesian-water supply in this region the catchment area must be either in the Precarboniferous rocks of the central mineral region and the Wichita Mountains or in the Guadalupe and connected ranges. That such a catchment area exists on the south is fully proved by the powerful springs at Lampasas and in San Saba County, all of which have their origin below the rocks of Carboniferous age. Some of these springs, such as the Lampasas, have their vent through rocks of this period, but they belong to the very lowest strata, and the temperature of the water proves that it comes from still greater depths. All such water is highly mineralized, but much of it seems suitable for general uses after exposure to the air has dispelled the sulphuretted hydrogen. Others of these springs, like that at Cherokee, San Saba County, spring through rocks below the Carboniferous, and these furnish water of an excellent quality. The dip of these rocks is much greater than the overlying Carboniferous, and the water supply would therefore be rapidly carried beyond the depths of ordinary artesian borings. The conditions of outcropping strata are similar in the Wichita Mountains to those of Llano and San Saba Counties, but we have no such evidence in the way of springs to prove their value, and no boring has been carried far enough to test the matter, although preparations are now under way to do so. No rocks of similar age have been observed in the Guadalupes. We must therefore conclude that, while the artesian conditions of the central basin are not unfavorable, the probabilities are against securing an adequate supply of water sufficiently free from mineral matter to be of use for general purposes (unless it be from the sandstones of the Guadalupe Mountains which

would require sinking to impracticable depths in most places). All exceptions will be of purely local extent and will require much local topographic and geologic work for their designation.

There still remains the area of the Staked Plains formation to be discussed, but our knowledge of its geology is too limited to permit anything but the most general statement. The upper portion of these plains is composed of strata of later Tertiary or possibly Quarternary age, underlaid by a conglomerate and sandstone, probably of earlier date than the Trinity sands, and dipping southeast. It is this bed that furnishes the surface-water of the plains, and from it gush the head-waters that form the Colorado, Brazos, and Red Rivers. The beds underlying this are probably Permian on the southern border, but newer formations may intervene towards the north. It is possible that this conglomerate bed may yield artesian water near the western border of the State, and I understand that one such well has been secured. It is my opinion, however, based on such knowledge as I can obtain, that the probabilities of artesian water on the plains are rather unfavorable than otherwise.

It will require a considerable amount of work in eastern New Mexico to decide the matter finally.

The well at Pecos City most probably belongs to the series described under the Grand Prairie region, and therefore gives us no clew to the area north of it.

The Trans-Pecos Mountain district, from the Guadalupe to the Rio Grande, consists of numerous mountain ranges and detached peaks, which rise from comparatively level plains. These plains are composed of loose material which has been derived from the erosion of the mountains, and sometimes has a thickness of over a thousand feet, as is proved by the deep wells along the Texas Pacific and Southern Pacific railways. The geologic formations of the mountains themselves consist of granites, sandstones, schists, and quartzites and Silurian, Carboniferous, and Cretaceous limestones. The whole area is faulted, broken, and cut by intrusive porphyries, basalts, granites, and other eruptives.

These conditions of structure prevent any other than a general unfavorable report on the district, although in certain localities conditions may, and probably do, exist favorable to the securing of artesian water.

In conclusion I may say that before making any more definite statement than the above it will be necessary that we have the topography of the greater part of the area accurately mapped, and a better knowledge of the details of its geology than we have yet had time to secure.

REPORTS OF FIELD AGENTS.

REPORT OF F. S. UNDERHILL, DIVISION FIELD AGENT FOR NORTH DAKOTA.

The following is a summary of the reports of artesian wells, found in the district of North Dakota, dividing the developed territory into sub-districts:

SUB-DISTRICT NO. 1—DEEP ARTESIAN WELLS.

This district includes the counties along the James River. The land is principally a high rolling prairie, at an average elevation, north of Jamestown to Devil's Lake, of about 1,520 feet, and south of Jamestown to the dividing State line from South Dakota it has an elevation of about 1,340 feet. The southern part of the James River Valley widens to a broad level in the counties of La Moure and Dickey.

The general formation of this subdistrict is a defined basin or slope, and is comprised within an area bounded by Devil's Lake on the north to the divide between the Cheyenne and James Rivers on the east, and from the divide between the Missouri and the James Rivers on the west.

The stratification of the wells is practically the same all through this subdistrict, and the water is similar in quality and effect.

Number of flowing artesian wells, subdistrict No. 1.

Town.	County.	Altitude.	Depth.	Flow.	Pressure.
		Feet.	*Feet.*	*Gallons.*	*Pounds.*
Jamestown	Stutsman	1,395		537	95½
Ellendale	Dickey	1,300		1,700	145
Oakes	do	1,350	947	900	135
Devil's Lake	Ramsey	1,467	1,550	100	30
Total				3,237	405½

At Bismarck, altitude 1,677, water formation not reached.

The flow of the artesian wells in this district is fully maintained, with a slight increase at Devil's Lake and a large increase at Ellendale, the waters of which have been used for irrigation only to a limited extent.

At Jamestown and Ellendale the water is used on lawns, trees, and shrubbery with good results.

At Oakes the first flow was obtained last fall, and it was allowed to run out on a flat covered with grass, and was turned away from it this

spring, and the grass upon which the water was turned is much better than that which surrounds it. It is used for city and general purposes. Horses and cattle drink of it freely.

The flow from the artesian well at Devil's Lake contains large quantities of sand, and it is unfit for use until permitted to settle, and is only used then to a limited extent.

The following is the log of a new artesian well at Devil's Lake, and is not included in the foregoing table. Being of interest it is herein inserted:

DEVIL'S LAKE WELL,
June 30, 1888.

The well was put down by Swan & Company.

August 11, 1888.—The drillings in the main well were continued the same as heretofore, namely, dark blue clay or soapstone, an ancient sediment closely resembling the formations to be seen in the lignite coal which is being mined in many parts of the Territory.

September 8, 1888.—The artesian-well drill touched 1,000 feet from the surface Thursday afternoon and is now fast approaching the 1,100-foot level. At 1,010, the drill struck a hard streak composed of gravel and sand, very similar to that to be found along our lake shores.

September 15, 1888.—The drill has passed the 1,100-foot level in the artesian well. Most of the week has been spent in putting down the 5-inch pipe which now reaches 1,000 feet into the earth. The formation is very similar to that previously reported, a heavy soapstone. An examination of a specimen taken from the bottom yesterday shows distinct traces of sand in the hard black sediment.

Wednesday preceding, the well was 1,167 feet. The work on the well was temporarily suspended for the purpose of constructing a patent rimmer to be used. Several hard streaks have been encountered within the last 100 feet of drilling. These hard streaks consist of limestone, sand, flint, gravel, and iron sulphurets, intermixed with the ever-present blue clay or soapstone, forming a conglomerate harder than cement. The 4-inch drill passed through them safely, but in rimming out the hole to admit the 5-inch pipe the ordinary tools for this purpose have been found inadequate. The presence of hard streaks or conglomerate are regarded as favorable indications of a flow of water which may be expected at any time.

November 17, 1888.—The well is down 1,430 feet. The drill is still in soapstone intermixed with conglomerate and little sand; the latter is a good indication.

November 24, 1888.—About 10 o'clock Monday morning the drill in the artesian well touched a stratum of sand at a depth of 1,431 feet from the surface, and within three minutes the water was flowing out of the top of the pipe. It was quite a sudden as well as an agreeable surprise. Only two hours before the sand rock was reached the contractors were about ready to quit in despair, as they had been thirty-six hours in the "hard streak" closely resembling the granite or archæan formation below which water is never found. "It is the toughest patch we ever put a drill in, said one of the contractors, and our drills have been broken and the blades otherwise ruined, making further progress seemingly impossible." The drillings from this hard streak showed fine granite and iron pyrites in about equal proportions, all firmly intermixed and cemented together. By 6 o'clock in the evening (eight hours from the time the sand rock was reached) the drill had gone down nearly 30 feet. Samples of the water were carried away and a few simple tests were made to ascertain its character. Drilling was suspended at 6 o'clock, and the work of rimming out the hole above the "hard streak" was commenced. The rimmings soon stopped the flow of water. By Wednesday afternoon the pipe had been driven down to within a few feet of the sand-rock and the pumps were lowered for the purpose of removing the débris. The force of the water has filled the hole with about 50 feet of fine sand which runs as fast as the pumps take it out.

December 1, 1888.—The pipe ordered from Chicago, 5 inches in diameter, was put down in the well. The Inter-Ocean sent several samples of the sand-rock and the hard strata above it, to Professor Montgomery, of the Grand Forks University. The following reply from him will be of interest.

"I have to congratulate you and the good people of Devil's Lake upon your success in the search after water. Place no confidence in the old idea that when granite or any hard rock is struck there is no use of boring farther. At Grafton (in subdistrict No. 2) when either granite or gneiss rock (these can not be distinguished by their borings, but only in large masses) had been reached, the "plant" was withdrawn. Then samples of pulverized borings were sent to me as well as to various university professors in other States, and reports on these were received by the Grafton city council. The Harvard University professor and myself recommended them to con-

tinue boring for 50 feet at least, but the "plant" having been removed by the contractor they were unwilling to risk the extra expense that would have to be incurred by replacing it and resuming operations. Consequently they closed up the 912 feet bore below 400 feet, from which latter they allowed a flow of inferior water that had been previously struck on their way down. The depth, 1,431 feet, at which you have struck water, is not far from my conjecture written to you last winter. I should not expect water much before 1,500 or 1,800 feet beneath the surface in the vicinity of Devil's Lake. There are various artesian wells over 2,000 feet deep. If necessary, I should continue 500 or 600 feet farther. Two of the samples you sent to me are iron pyrites (sulphide of iron), and the third is a water-worn hornblende stone, very interesting, because having been water-worn before being deposited where you found it."

February 19, 1889.—The drill was put in the well yesterday for the first time since the sand was struck. The 3½-inch pipe is now down 1,510 feet. Thursday evening the sand pump came in contact with a hard substance, and it was supposed to be another streak of conglomerate. When the drill was put in it soon passed through this hard streak into loose sand which came up into the pipe, and last evening the contractors were using the sand pump again. The formation now shows but little change from that first encountered when sand was struck two months ago.

February 28, 1889.—But little progress can be reported for this week's operation in the artesian well. During the entire week, with great labor, the contractors succeeded in driving the 3½-inch pipe about 3 feet below the point reached last week. They are still in the quicksand, which is too soft for drilling and too spongy and binding for rapid driving. The total depth reached at 6 o'clock last night was 1,520 feet from the surface.

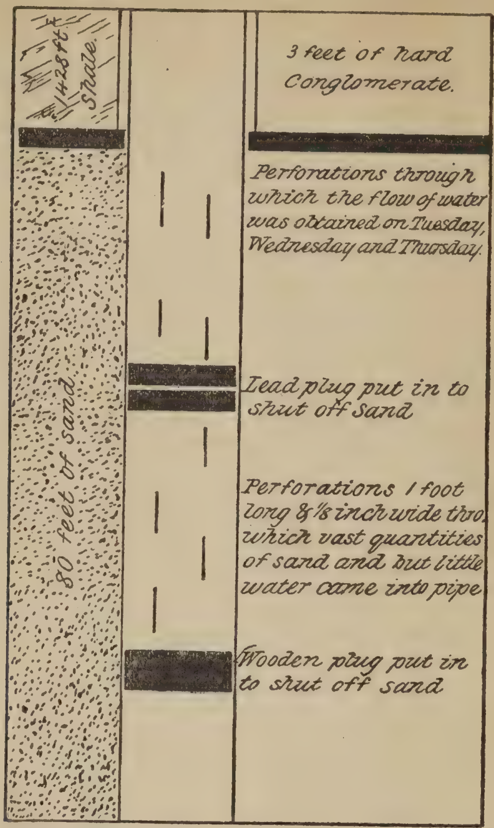
June 1, 1889.—Wednesday noon all hope of exhausting the sand that continued to flow through the perforations in the artesian well pipe was abandoned and a lead plug, 4 feet long and 3½ inches in diameter, was put down to a point 10 feet above the perforations (about midway of the 80-foot sand bed), and by means of the drill the plug was flattened at the top so as to make a complete barrier of the inflowing sand. The pump was put down and by 10 o'clock yesterday morning the fine sand which remained in the pipe after the lead plug was put in had been exhausted. Then the perforator was put in and an incision of about 1 foot long and one-eighth of an inch in width was made. Considerable water came through and also some fine sand. It is the intention of the city council to exhaust every resource in this attempt to get water. Between $6,000 and $7,000 have been spent thus far in the well itself.

June 15, 1889.—The artesian well commenced to flow again by 9 o'clock Wednesday evening and continues to pour out its crystal waters at the rate of 60 to 80 barrels an hour. This is the largest flow that has been obtained up to the present time. The water shows very small particles of fine sand, which is considered a good indication. The water is of the same quality as above, very soft and pleasant to the taste.

June 22, 1889.—One hundred barrels per hour is the estimate now placed on the flow from the artesian well. Wednesday the stream grew weak and the perforator was used. Later in the day the sand pump was again put in and when it came up the water ceased to flow. The pump was used until midnight and at an early hour Thursday morning the flow started again. It has greatly increased in volume ever since, and last evening it was larger than at any time since it commenced. The beauty of it is the sand continues to flow up with the water and it is estimated that the amount of sand thrown up is not less than three tons per day.

June 29, 1889.—Work was resumed upon the artesian well Monday morning. Another perforation was made in the pipe about 20 feet below the cap-rock. As was expected, the water stopped flowing. The pump was then used. Thursday morning a similar flow started. Failing to increase, another incision or perforation was made Wednesday and the flow again stopped. The pump was used again until Thursday afternoon when the water showed a disposition to run and work was suspended. Friday morning the well was spouting both water and sand and is still at it.

June 8, 1889.—In this issue is a diagram of the lower section of the well.



SUB-DISTRICT NO. 2.—ARTESIAN DEEP WELLS.

This district includes the counties of Walsh and Pembina, in the lower Red River Valley. The land is flat and level, and has an average elevation of 840 feet. There are two artesian wells in this subdistrict, and the character of the stratification and the quality of the water are quite different from those found in subdivision No. 1.

Number of flowing artesian wells in subdistrict No. 2.

Town.	County.	Altitude.	Depth.	Flow.	Pressure.
Grafton	Walsh	900	925	700	20—not used.
Hamilton City	Pembina			980	
Total				1,680	

The water from these artesian wells is salty, and cannot be used.

SUB-DIVISION NO. 3.—SHALLOW ARTESIAN WELLS DISTRICT.

This district includes the counties of Grand Forks, Trail, and Cass (?) and the Red River Valley. The land lies flat, at an average elevation of about 900 feet.

Number of wells in subdistrict No. 3.

	Flow per minute.	Pressure.	Irrigation.	Remarks.
	Gallons.			
Hillsboro (A. M. Anderson)	15	....	None ...	Farm and domestic use.
Casselton (Casselton Roller Mill)	22.5	8.5	...do	Steam-power and domestic use.
Grandin (A. Armstrong)	50	12	...do	Farm and domestic use.
Watermere (Hunter)	33	10	...do	Intended for city supply.
Total	120.5	30.5		

The great number of small flowing wells in this subdistrict, as appear by the reports, show an average flow of about 22 gallons per minute and having an average depth of about 250 feet and steadily maintain the quantity of flow indicated. The water is clear, hard, and a little salty. A few cases have been reported where it has been injurious to vegetation, but investigation shows that when the grass is not flooded it does it no harm. It is used for general farm and domestic purposes and live stock are reported to be fond of it, and its use is considered beneficial and healthy.

Of these shallow and small flowing wells there are several hundred in Cass County and about three hundred in Trail County; also a number in Grand Forks County. The reports show that they are of uniform character and establish the fact of this being a distinct well district in its character.

Table of artesian wells in North Dakota by sub-districts.

Sub-district number.	Number of flowing wells.	Total flow, gallons per minute.	Average flow.
1	4	3,237	809¼
2	2	1,680	840
3	*12	264	22
	18	5,181	1,671¼

* Reported as an example of a large number.

The balance of the area of the State of North Dakota has no artesian well system at present developed.

REPORT OF STEPHEN G. UPDYKE, DIVISION FIELD AGENT FOR SOUTH DAKOTA.

The territory comprising the district embraced in this report is that part of South Dakota lying east of the Missouri River south of the third standard parallel and the south line of Beadle, Hand, and Hyde Counties and west of the ninety-seventh meridian.

For convenience of description and reference this territory is divided into subdistricts, numbered one, two, three, and four, respectively, which will be discussed or referred to in relation to the deep artesian basin.

A fifth or supplementary subdistrict is added formed out of portions of the first three above, and will be considered only in relation to the shallow artesian basin.

SUB-DISTRICT NO. 1.

This includes Kingsbury and Miner Counties and those portions of Brookings and Lake Counties lying west of the ninety-seventh meridian, and for convenience is denominated the *unexplored* subdistrict, throughout which no borings have been made to a depth sufficient to reach the deep artesian water basin, or to show what the geology really is.

Many favorable features are presented which would indicate this district as a proper and desirable field for experimental operations in deep well borings for irrigation purposes, and storage reservoirs could, with slight supplementary labor, be established in many portions of it.

The following table shows the altitudes at several points, where wells have been commenced and for various reasons abandoned.

The estimated depth of the deep-water basin is indicated by wells bored in the surrounding neighborhood:

Wells.	County.	Altitude.	Deepest bore.	Estimated basin.
		Feet.	*Feet.*	*Feet.*
Iroquois	Kingsbury	1,400	600	925
De Smet	...do	1,726		1,250
Lake Preston	...do	1,696		1,420
Arlington	...do	1,850	800	1,375
Brookings	Brookings	636	800	1,160
Vilas	Miner	1,480	500	1,000
Clark	Clark	1,785	1,100	1,300

Brookings and Clark lie outside of this subdistrict, Brookings to the east and Clark to the north, and are added to the list of altitudes to show that had they not been abandoned, they could have been contin-

ued to such an extent as to determine the depth from the surface to the artesian basin.

Deep-well boring is now being done at Iroquois, Kingsbury County, and at Vilas, Miner County, and when finished they will be the first in the subdistrict of value in determining the eastern or southern extent of the artesian basin.

Wells are also being bored at Madison, Lake County. One has gone to the depth of from 300 to 400 feet; it is not known whether quartzite would be struck above the level of the artesian basin; but a thorough attempt is now being made to test the matter. Another is to be bored to the depth of 1,500 feet.

This district is practically unexplored, and it is a proper field for such boring as will show its character. Should water flow at the United States experiment station at Brookings the director would gladly conduct a series of experiments, the results of which, when published to the farmers of the State, would be of great service to them, and this is a good place to make an experimental bore.

In the vicinity of Lake Preston and Arlington there are large natural storage basins which, with a small amount of additional work, would store sufficient water for the western slope of the Big Sioux River and the lands south of Kingsbury County, and should the local storage prove insufficient for the waters found another basin exists at Madison, Lake County, of equal capacity, to which the water may easily be conducted for use on the more southern lands.

With these advantages of natural storage it is suggested that in the eastern portion of this subdistrict a thorough experiment for artesian water should be made by making deep borings at Lake Preston and at Arlington.

FACTS FOR AND AGAINST EXPERIMENTS.

(1) A well flows at Highmore at an elevation of 1,886 feet, a higher point by 36 feet than Arlington.

(2) The city well at Huron, at an elevation of 1,275 feet, flows with a pressure of 120 pounds, which would raise water to an elevation of 1,550 feet, which would indicate a flow at Iroquois and Vilas only.

(3) The city well at Woonsocket, at an elevation of 1,260 feet, flows with a pressure of 153 pounds, which would raise water to an elevation of 1,612 feet, an indication of a flow at Madison, unless that, as at Vilas, it is in peril from the quartzite.

OUTLOOK FOR THIS SUB-DISTRICT.

It is a proper field for experiments. Should water be reached at Lake Preston and Arlington, there is at hand in townships 109, 110, and 111, ranges 54 and 55, a great natural reservoir system which with slight supplementary work would furnish 300,000 acre-feet of storage, and which would command the southwest portion of this subdistrict which last year suffered most from drought in South Dakota.

It should be remarked that water at Arlington could be distributed eastward to all the western slope of the Big Sioux River if there should still be a surplus. An equal reservoir system lies southeast of Madison, Lake County, which at no greater cost, would serve the country still further south.

Specimen bores.

Hetland, Kingsbury County.		Arlington, Kingsbury County.	
Sec. 19, T. 112, R. 53.		Sec. 21, T. 111, R. 53.	
Black loam	2	Black loam	2
Yellow clay	48	White and yellow clay	8
Blue clay	235	Dark yellow clay	40
Soft yellow clay	25	Blue clay	160
Shell rock	50	Grayish clay	160
Yellow clay	60	Blue shale	415
Blue shale	290	Sandstone	1
Total	710	Total	786
Stood up well; no casing; hole dry from top to bottom.		25—111—53, same as above to 485 feet.	

It should be added that the bores at Arlington were begun for shallow wells, and with no idea of reaching the deep basin, and were abandoned because the machinery was not adapted to deep boring. The bores now in process, as Iroquois and Vilas are the first attempts for a thorough experiment for deep water. If successful at Vilas the attempt is to be made at Madison at once, while Lake Preston is only waiting for results at Madison and at Clark, where the drill is lost at a depth of 1,100 feet.

Land in this subdistrict is valued from $5 to $20 per acre. Irrigation is much desired for autumn use each season, and for about one-fifth of the rest of the year. The average estimate is that irrigation would double the value of the land, while others estimate an increase thereby of four and even five fold. Trees have done well in this entire subdistrict, having for the most part been either mulched or watered from surface wells, and irrigation has been slightly practiced in gardens, but always with excellent results.

Much thought has been directed during the last year to deep plowing, fallowing, and furrowing, in order to husband the rain-fall. But a deeper feeling prevails that as the early seventies and eighties were moist years, and only two to three of the later years of these decades dry, that so it will be in the nineties. This feeling is confirmed by the Indians at Flandrau, who predict great rain and snow for 1891 and 1892, and also by the present season, which, though without much rain before May, found the soil in a most excellent condition for the seed, and has since then been characterized by a plentiful fall of rain.

SUB-DISTRICT NO. 2, OR THE GRANITE BASIN.

This subdistrict includes all of McCook County, and those portions of Minnehaha, Turner, and Clay Counties lying west of the ninety-seventh meridian, and also those portions of Hanson, Hutchinson, and Davison Counties lying east of the James or Dakota River. In this subdistrict the quartzite shows an elevation or back-bone extending westward from Sioux Falls to the James River.

Altitudes of this sub-district.

	Altitude.	Remarks.
	Feet.	
Sioux Falls	1,387	Granite at surface.
Salem	1,517	Granite at 270 feet.
Parker	1,340	Granite at 260 feet.
Alexandria		
Vermillion	1,161	Granite at 630 feet.
Centreville	1,233	
Hurley	1,272	
Rockport		Granite at surface.
Section 11, T. 103, R. 57: Stopped in red stone at 97 feet.		
Section 10, T. 103, R. 57: 2 feet of red stone at 130 feet, 2 feet at 210, and 7 feet at 270.		
Section 23, T. 103, R. 57: Quarry of Sioux Falls granite.		

The following comparisons are of value—

	Feet.
Mitchell quartzite at	545
Plankington quartzite at	760
Tyndall quartzite at	735
Scotland quartzite at	548

Hazleton Post-Office, Hanson County, is the center of the artesian well district, twenty or more being in sight of that place. Their average depth is from 80 to 250 feet, and their flow varies from a very small one to that of a full 6-inch diameter stream.

This subdistrict lies well within the great corn belt of South Dakota, where wheat succeeding corn gathers so much of the advantages of the fallow, and where either crop has thus far been successful, its only foe being the grasshopper.

It has the same rich soil and clay subsoil of subdistrict No. 1. It has an older civilization, and being benefited by former years of tillage it does not need artesian irrigation. The brooklets rising to the north are here found to be fine streams, which are sometimes dammed and stocked with fish or used to overflow the meadows; and it also has many springs lying too low for upland irrigation, that swell the waters of the Vermillion, the James or Dakota, and the Sioux Rivers.

Moreover, the lowland valleys are broader here than farther north, and the upland with the lowland tillage continues to find adaptation to the season.

SUB-DISTRICT NO. 3, OR THE MISSOURI BASIN.

Includes the territory lying south of the second standard parallel and east of the Missouri River and west of the James or Dakota River, being whole of the counties of Buffalo, Brulé, Jerauld, Sanborn, Aurora, and Douglas, and portions of Charles Mix, Hutchinson, Davison, and Hanson.

This basin strides the quartzite ridge sloping westward around Rockport, Hanson County (Sec. 6, T. 101, R. 58) and is struck at Mitchell, Davison County, at 545 feet at top; Plankington, Aurora County, at 760 feet below the surface; compare Tyndall, 735 feet, and Scotland, 548 feet.

Wells of deep bore.

Name.	Section.	Township.	Range.	Flow.	Depth.
				Gallons.	*Feet.*
Daniel Schmitt	11	108	64	150	725
Chas. Nelson	23	106	65	....	725
Letcher City	15	105	61	175	600
Woonsocket	28	104	62	2,750	725
Mitchell	22	103	60	175	546
Plankington	Two city mills over which a law-suit pends.				
Hattons	34	104	64	2½	545
White Lake	14	103	66	150	950
Kimball	3	103	68	300	1,068

This sub-district possesses no natural reservoir systems for artesian storage other than the sloughs and small lake-beds which could be artificially dammed across at intervals for evaporation.

Water should be reached throughout its extent at a depth of from 500 to 1,100 feet, and the land lies well for an evaporation or surface-irrigation system, though in the latter case the ditches must run directly from the wells and the surplus water be stored in valleys for evaporation.

It is a beautiful country, its average value from $4 to $15 per acre. The soil is a deep black loam, under which lies clay of a yellow and then of a blue color, and beneath which lies a thin strata of chalk and more clay. The few springs that are found in this district lie at the base of the Missouri River Bluffs or in other places so low that they can not be improved for use.

Its imperative need is water, of which the source must be artesian. Pumping wells often reach 250 feet before a supply is found, though in the vicinity of an artesian well it is found at a shallow depth.

Wells in Sub-district No. 3.

Name.	Location.				Flow per minute.	Depth.
	Section.	Township.	Range.	County.		
					Galls.	
Woonsocket	28	107	62	Sanborn	2,750	725
Letcher	15	105	61	Sanborn	175	600
Daniel Schmitt	11	108	64	Jerauld	150	725
Charles Nelson	23	106	65	Jerauld	....	....
Mitchell	22	103	60	Davison	175	546
Kimball	3	103	68	Brulé	300	1,068
Hattons	34	104	64	Aurora	2½	545
White Lake	14	103	66	Aurora	150	950
Plankington*	......	......	......	Aurora	....	....

* Suit pending over these two city wells.

SUB-DISTRICT NO. 4.

This sub-district comprises Bon Homme and Yankton Counties. The southern boundary of these counties is the Missouri River.

Quartzite is struck at Cyndall at 735 feet and at Scotland at 548 feet below the surface. In Yankton County the water-bearing sand has been penetrated 200 feet and the pink sand overlying the quartzite reached at a depth of 715 feet. This subdistrict is most interesting, as touching the question of the volume of artesian water supply.

In Yankton County many wells have fallen off in flow and pressure. The great flow at Yankton was 1,623 gallons per minute, and the heaviest pressure was 56 pounds, now fallen to 52, while many wells of lesser flow and pressure have decreased in greater degree.

The question has been started whether the source of these artesian waters has not been limited by the flow of greater volume in subdistrict No. 3.

A personal examination of these wells has suggested to me several reasons against such a conclusion, one of which, though not the strongest, may be properly inserted here.

If Yankton wells decrease from other than local causes then so would those of Bon Homme, though in a lesser degree; but wells in Bon Homme County remain the same as at first, with four exceptions. Scotland, which flowed at first irregularly, has been stopped mechanically, and the other three are increasing. I have grouped these Yankton wells with those of Bon Homme, because in Bon Homme County three wells report an increasing flow, while the remainder (except one mechanically stopped) report a flow constant from the first.

Comparison of Yankton and Bon Homme Wells.

Wells.	Depth.	Flow.	Pressure.	Temperature.	Increased or diminished.	When bored.
Yankton County.						
Pressed Brick Company	595	1,623	56–52	60	Diminished	1886
Asylum	672	120¼	15–13	64	do	1889
Yankton City	615	15–900	18–7	62	do	1886
Sec. 12, T. 93, R. 56	375	8–6	25–20	60	do	1887
Sec. 11, T. 93, R. 56	380	1½		60	do	
Sec. 17, T. 93, R. 56	400	25–12	45–35	60	do	1885
Bon Homme County.						
Scotland	587	15			Stopped	1885
Tyndall	636	552	38	62	No change	1887
Sec. 19, T. 94, R. 58	578	7	10	60	do	1887
Sec. 34, T. 95, R. 59	734	97	36	61	do	1889
Sec. 20, T. 94, R. 59	649	13	45		No change	1889
Sec. 31, T. 94, R. 58	645	100	40	62	Increased	1890
Sec. 5, T. 93, R. 58	665	250	42	62	Increasing	1890
Sec. 1, T. 93, R. 59	646	40	60	62	do	1889

It should be said in connection with the Yankton wells that some may have filled at the bottom and are now served by the upper and weaker flows, but undoubtedly many of these wells are of imperfect construction or have become impaired by use. With shales underlying 200 feet of chalk, the water finds outlet through fissures unless the casing is driven to the clay beneath and to a solid footing and then sealed to piping reaching to the water-bearing strata. Within a month of the completion of the Yankton City well the water broke from the chalk bluffs (more than 1 mile away), in springs estimated at 1,000,000 gallons per day, and in the last four years the well has lost 12 pounds of pressure.

It is the fact that in township 105, range 57 (Miner County), containing thirty-three shallow wells, no plows are found in sections 2, 11, 14, 23, 26, because a large spring in section 2 and a bubbling lake in sections 11 and 14 exhaust the pressure in these sections.

Again, Mr. Sromhor's well, in Yankton County (sec. 11, T. 93, R. 56), has very much diminished, because leaky piping permits the water to charge the soil for 50 feet in breadth for a great distance down the slope. These observations are insufficient to warrant more than the opinion that their diminution has a local cause in every case, and does not touch the question of limitation in connection with the source of these waters. If

perfectly constructed and unimpaired wells in Yankton should diminish in flow and pressure, the cause could not be traced further than the granite backbone over which the Yankton and Bon Homme waters flow through high and low pressure sections of the water-bearing sand.

This is the cause of much lower pressure in this subdistrict than in the others at the same altitude, and if wells should be multiplied beyond its capacity to carry water, the effect would appear in both Yankton and Bon Homme wells, and until bores in Charles Mix and Douglas Counties shall show that the deep water and high pressure strata are continuous from the third to the fourth subdistrict it will be irrelevant to conclude from the diminution at Yankton anything as to the limitation of the artesian water supply of the Dakotas.

The western portion of this subdistrict is a fine rolling country sloping gradually to the Missouri River, and it is characterized by a subsoil that absorbs a vast amount of water.

From Mr. Zemart's well (sec. 34, T. 95, R. 59) of 97 gallons per minute a service is reckoned for upon 20 acres only. An inch flow in a ditch 1 foot wide was three days in reaching a point 400 feet distant, and Mr. Z. estimates that a 6-inch well would irrigate no more than one section of land. In boring this well 100 feet of sand and fine gravel were found just below 4 feet of nice black soil.

The average worth of land in this subdistrict is $20 per acre, and farmers freely claim that in Bon Homme County irrigation would increase this value to $75 per acre.

SUB-DISTRICT NO. 5, OR SUPPLEMENTARY DISTRICT OF SHAL LOWWELL DISTRICT.

This district includes townships 104, 105, and 106, and ranges 56 to 60, inclusive, with small additions to the northwest and some exceptions to the northeast, and is situated in McCook, Hanson, and Danson Counties. It is characterized by many low-lying springs of artesian origin, and has about 150 shallow wells, and is a basin of sand or gravel lying under clay, at unequal depths, and overlying so far as determined the red stone. This district is a finely rolling country, gradually descending to the south and west.

Pressure and flow are not always greatest at the lowest altitudes, though some of the finest wells are found near the Rock and Blue Earth Creeks.

A study of my notes confirms the statement of Mr. Updegrove, who bored many of these wells, that the highest pressure and the stronger flows are struck in the coarser gravel, while fine sand flows are very weak. A marked characteristic of the water is its temperature, running from 40° to 45° F., causing it to be used far more often for dairy purposes than for irrigation.

I believe these wells have a service quite independent of the locality or the deeper basin that certainly lies beneath its western portion, and in support of that conclusion I submit—

(1) The difference in temperature 40° and 60° F.

(2) From many sources I learn that bores to the north reach water that courses up from about the level of this sheet of gravel and water to near the surface.

In south Kingsbury County and in Brookings County, to within 15 or 20 feet, there is a great deal of this testimony that I have not had time to tabulate or arrange which points to a connection between these waters and the surface waters of Day and other northern counties of this State, that have no outlet unless it be under ground.

The lake beds around Preston a few years ago were full of water, they are all dry now but one or two; those at Madison are very much lowered below their outlet, a fact fully accounted for by the evaporation of dry years; but there has been very much more rain in north Coddington and in the lake region, spreading fan-like to the north, and this water does not run off or deposit itself in Sioux River, but into the lake-beds, the natural storage grounds of the district; the water first coming to a flow in Grant County, and then depositing itself in the ground of the shallow well district.

Analysis of water from city well at Yankton.

[By Prof. E. B. Stuart, Chicago.]

	Grains.
Calcium sulphate	27.397
Magnesia sulphate	23.304
Calcium sulphite	5.439
Chloride of soda	1.179
Magnesia carbonate	24.455
Silica	.094
Trace of iron in solution precipitated on exposure to air	.026

Stratification of brick-yard well at Yankton.

[Karr and Kicher.]

	Feet.	
Soil, sand, and gravel	38	
Chalk rock	62	100
Shale	26	126
Hard rock	4	135
Sand	34	164
Shale	65	224
Sand	35	259
Shale	135	389
Sand and clay in alternate layers, with water in each vein of sand	100	489
Water-bearing sand	106	595

501 put at 6-inch pipe in this well, and 60 feet below the bottom of pipe reamed out to 9 inches diameter.

GENERAL REMARKS.

The question of irrigation has, during the last year, been brought very prominently to the attention of the people, on account of the drought of the previous year.

Though all the large wells, and some of the smaller ones, have been bored by the use of steam, I find the use of horse-power very common. In Bon Homme County I found two drilling machines operated by means of horse-power. In the shallow wells district the latter power is easily capable of doing the work. The horse-power machines bore very fast.

In the whole of my division, with the exception of the first and third subdistricts, the people are in possession of the facilities, and are themselves able to perform the labor necessary for boring all the wells needed. But I am positively of opinion that the unexplored district (the first) and the Missouri district (the third) should be considered as in need of the larger and more extensive class of irrigation operations. The wells generally in my division are reported as being used for ordinary domestic and farm purposes, or for city uses, with the following exceptions:

At Yankton there is one well the water from which is used for power purposes.

In Brulé County, at Kimball City, the waste water forms a pond well stocked with a certain species of fish, and from which about 4 tons of one kind, commonly called bullheads, were taken in the years 1888 and 1889 respectively.

In Aurora County, at White Lake, the waste water is conducted by open ditch for half a mile to the farm of G. C. Bryan, forming a lake covering a surface of 5 acres, which was stocked with carp in 1888. In 1889 an acre of garden was irrigated. The beneficial effects produced upon the soil in the vicinity of this lake and garden, which is reached by the percolation of some portion of the water is strikingly noticeable both in the increased quantity and better quality of the wheat, hay, vegetables, and fruits grown thereon. Especially noticeable was the effect upon the strawberry and sugar-beet. The product of a patch of the former on the farm above named, killed by drought the previous year, was increased.

In McCook County the well of Gurney Brothers (sec. 20, T. 104 R. 56), with a capacity of 25 gallons per minute, was bored expressly for irrigating purposes. It is located in the center of and upon the highest point in a garden of 4 acres. The water is conducted to the four corners of the tract by means of four ditches, like the furrow made by a plow, and is thence conducted between the rows of garden produce by means of smaller ditches made by the hoe. Subsoil: 20 feet, yellow clay; 65 feet, blue clay. Temperature of water, 45° F. This well should be considered as a type of several wells found in Yankton County, so far as results are concerned.

In Bon Homme County the Peter Boyune well (sec. 5, T. 93, R. 58) was bored in February and March of this year. Depth, 665 feet; flow, 250 gallons per minute; pressure, 42 pounds; temperature, 62°. Mr. Boyune has conducted the water into his garden with very satisfactory results, and prepared 40 acres for irrigation.

The well of G. C. Cooley (sec. 19, T. 94, R. 58) is 578 feet deep. It flows 7 gallons per minute with a pressure of 10 pounds and a temperature of 60°. Mr. Cooley has experimented by conducting water from his well among his trees with very gratifying results.

The well of Mr. Zeunart (sec. 34, T. 95, R. 59) irrigates his garden with satisfactory results.

ARTESIAN WATERS NOT FLOWING.

As we pass north of the fifth sub-district in northwest Miner Co., there are many bores of like character with those to the southwest that reach the artesian water, the sole difference being that the elevation of the surface has become too high for the pressure of this sheet of water. To determine the extent of this basin would require bores not yet made and time not given me. The dry bore of 710 in sec. 19, T. 12, R. 53, at an elevation of 1,850 feet, was not deep enough to find this sheet of water, and the records at Brookings, Iroquois, Vilas, and Clark are not yet at hand, or not instructive as to the extent of this basin.

Borings in subdistricts No. 2 and 5 of this character exist, but interest in them has ceased to such extent that correspondence alone has developed nothing more than names of persons who might give information and these in turn have recommended me to others or have not answered. General mention of them without location or characteristics is all I have, but I think that an inquiry into the characteristics of "deep-pumping wells" would bring it out, being a form of inquiry better adapted than that I have made use of while in the field.

Though I have incidentally spoken of our springs as being of light flow and low lying in the vicinity of streams and rivers, I will report separately that there practically are no springs in my division for purposes of irrigation with the exception of Wessington Springs. They are superseded for practical purposes by streams or wells in the vicinity. The following extracts are given from letters I have received. They present some useful information:

Buffalo County.—John Grace (Duncan post-office)—"There are springs in Sections 17 and 20, T. 108, R. 68. These are at the head of Crow Creek, but the ponds and the lakes are supplied from subterranean waters."

A. R. Merritt (Buffalo Center post-office)—"You will find a spring on Secs. 16, 25, 10, 68, and one near Gann Valley that sends out pure water that would fill a 3-inch pipe.

Brulé County.—A. A. Seppert (Red Lake post-office)—"Artesian well, is the only water that could supply this county. Red Lake is dry now, and the Missouri is too low."

Charles Mix County.—E. L. Bates (Bloomington post-office)—"No artesian wells, borings, nor springs in this vicinity. I think we are in the belt, but can not bear the expense."

Davison County.—George A. Thomas (Mitchell post-office)—"A spring on section 11 would fill a 6-inch pipe; it is on the river bottom close to the river. It runs out of a ledge of sand-rock that lies below the surface and is only about 5 feet above the river. The wells in this locality are all of small flow from 116 to 280 feet deep, and run from 10, 75, and 100 barrels a day. The water is found just above the Jasper or in the sand rock just above.

Hutchinson County.—John McClain (Tripp post-office).—We have no springs in this vicinity, but there are several along Emanuel Creek.

Jerrauld County.—A. R. Merritt (Buffalo Centre post-office).—"There are two small springs near Waterbury. There are a great many springs at Wessington."

Lake County.—E. C. Keith (Brant Lake post-office).—There are no artesian wells in this vicinity. Wells in this county sometimes go to 200 and even 400 feet, but we have never struck a flow in any of them. There is one spring 10 miles southeast of this place which flows quickly into Skunk Creek.

O. C. O. Overkin (Prairie Queen post-office).—"There is no artesian well or spring or flowing water in this vicinity to my knowledge."

Anthony Oron (Badus post-office).—"Have got many wells, but no water to supply them with yet."

Miner County.—James E. Delany (Vilas post-office).—"About thirty flowing wells, averaging a depth of 100 feet, with a bore of 2 inches. The water is not used for irrigation."

E. G. Reeves (Carthage post-office).—"Besides our wells, we have many springs of artesian origin, but they lie near the creeks and are of no account for irrigation."

Minnehaha County.—E. Fuller (Montrose post-office).—"We have several springs in this vicinity that flow all the time, but they lie close to East Vermilion, McCook County.

Sanborn County.—C. B. Hutchins (Cornell post-office).—"Our springs are all near the river. They contain some iron and are inexhaustible. The best flowing well in the United States is at Woonsocket."

Turner County.—M. Morris (Spring Valley post-office).—On sections 5 and 8 of township 97, range 54, there is a creek bed in which a number of springs come to the surface and others can be found by digging a very few feet. On sections 10 and 3 there are numerous springs; one discharges quite a flow of water, which empties into Turkey Ridge Creek. There are seven artesian wells in township and some very strong ones.

LAND VALUES.

The value of land in the first subdistrict is from $5 to $15 per acre, as it approaches markets. In the second subdistrict it will run as low, and from that up to $25 per acre, for land for exclusively agricultural purposes. In the third subdistrict it is from $2 up to $10 per acre; in the fourth, from $5 to $25 per acre. Irrigation would increase the value of land in the third subdistrict most, bringing it all up probably to $25 per acre and some of it to a much higher figure. In the first district it would double values, at least, and in Bon Homme County it would have a value equal to any place in my territory.

Summary of flowing wells in South Dakota east of Missouri River and south of second standard parallel (omitting many small wells in sub-district No. 5, or the secondary basin and shallow wells).

Sub-district.	No. of wells.	Total flow.	Average flow.
No. 1	None		
No. 2	None		
No. 3	7	3,600	515
No. 4	56	5,155	92
No. 5	50	1,500	30
Totals	113	10,250	90+

NOTE.—There are very many more wells in subdistrict No. 5, shallow wells district, which would lower the total average flow.

Detail of typical wells which lie east of the Missouri and south of second standard parellel.

	Flow per minute.	Pressure.	Remarks.
	Gallons.		
City of Mitchell, subdistrict No. 3.	175	7	Water stored in stone reservoir and pumped for city. No irrigation.
City of White Lake, subdistrict No. 3.	150	35	Mr. Ryan has a franchise for waste water and conducts it to his farm, one-half mile; irrigates 10 acres with fine effect on trees, beets, onions, strawberries, wheat, corn, grass, etc.
City of Kimball, subdistrict No. 3.	300	25	Waste water forms lake stocked with bullheads, of which 4 tons were taken in 1888 and in 1889. Surface wells in vicinity 250 feet; now it is needed to go only 50 thereabouts.
Gurney Brothers, N. W. Sec. 20, T. 104, R. 56, subdistrict No. 5.	*25	5	For garden irrigation with fine effect on vegetables and shrubs, trees on ground 20 rods away and 30 feet lower are reached by soakage and soil is very damp. The only well I found bored especially for irrigation.
Peter Byrune, N. E. Sec. 5, T. 93, R. 58, subdistrict No. 4.	†250	42	Has irrigated garden and pasture; conducts water to garden in pipes; is arranging for field irrigation; thinks he has enough water for 40 acres.

* Temperature 45. † Temperature 62.

Tabulated list of wells in Yankton and Bon Homme counties.

	Location.	Elevation.	Cost.	Depth.	Size.	Flow.	Pressure.	Change.	Sediment.	Use.	Stored.	Strata.
YANKTON COUNTY.												
Press Brick Co.	Yankton	6 A.	$2,500	595	6	1,620	52	None	Sand	Power		Sand and gravel, 33; chalk, 62; blue shale, 26; sand, 38; blue shale, 60; sand, 35; blue shale, 130; sand and clay, 100; water sand, 106.
Corporation	Yankton	60 A.	2,800	615	6	900	18	Diminished.	Pyrites, sand, and granite.	City use	In tanks.	Yellow clay, 25; blue clay, 30; chalk, 60; shale, 300; sand and clay, 195.
Asylum	Mile north	100 A.	2,860	672	4½	120	13	do	Sand	Asylum	No	Yellow clay, 25; blue clay, 30; chalk, 60; shale, 300; sand and clay, 195 to 600 feet; water sand, 72.
P. Johnson	Sec. 9, T. 93, R. 54	Ry	180	280	2	120	25	do		Stock	No	
C. West	Sec. 13, T. 94, R. 54	Ry	150	280	2	150	60	do	None	do	No	Sand, 5; sand, 125; blue clay, 100; sand rock, 50.
F. Luch	Sec. 9, T. 93, R. 54	Ry	150	265	2	30	32	do	No.	do	No	Sand, 5; sand, 125; blue clay, 100; sand rock, 50.
P. Larson	Sec. 10, T. 93, R. 54	Ry	140	275	2	25	26			do		Sand, 5; sand, 125; blue clay, 100; sand rock, 50.
Cement works	4 miles west	Ry		500	(*)							
J. A. Pierson	do	Ry	570	380	2	35	28			Stock	No	Sand, 140; shale, 190; sand rock, 50.
S. and Ferdinand	2 miles west	30 A.	600	400	2	60	60	No.	No.	Slaughter-house.	No	Chalk, 90; shale, 200; clay in layers, 110.
F. Sample	Sec. 2, T. 93, R. 55	Ry	260	400	1	50	30	No.	No.	Farm	No	Sandy soil, 15; sand, 105; clay, 100; sandstone, 155.
F. Osborne	Sec. 30, T. 94, R. 54	10 A.				6	12			do	No	
B. Hinman	Sec. 32, T. 94, R. 55	85 A.	500	500	2	8	12	No.	No.	do	No	
Y. Hanson	Sec. 30, T. 94, R. 54	15 A.	165	305	2	15	14	No.	No.	do	No	Sandy soil and clay, 50; sand, 95; clay and sand rock, 160. Favorable for irrigation.
T. Nelson	Sec. 27, T. 94, R. 55	15 A.			2	5	0			do		
H. Strunk	Suburbs	Ry	500	435	2	125	32	No.		do		Soil, 5; clay, 35; sand, 80; clay shale, 315. Favorable for irrigation.
J. T. M. Pierce	Sec. 31, T. 95, R. 56	90 A.		587	2	43	17	No	No.	do	No	Soil, 3; yellow clay, 30; blue clay, 60; chalk, 90; shale, 377; sand rock, 27.
F. P. Hardin	Sec. 31, T. 94, R. 54	Ry	125	286	2	16	40	No.	No.	do	No	Soil, 3; yellow clay, 30; blue clay, 60; chalk, 90.
G. M. Finnotte	Sec. 30, T. 94, R. 54	30 A.	250	342	2	30	...					Soil, 3; yellow clay, 15; blue clay, 20; sand, 130; shale, 174; very pure water.
A. L. Varrosdal	Sec. 17, T. 93, R. 54	Ry		300	2	30						Soil and clay, 5; quicksand, 125; clay, 45; chalk, 20; shale, 105.

*Abandoned because of broken casing and a new well now boring.

Tabulated list of wells in Yankton and Bon Homme Counties—Continued.

	Location.	Elevation.	Cost.	Depth.	Size.	Flow.	Pressure.	Change.	Sediment.	Use.	Stored.	Strata.
YANKTON CO.—cont'd.												
S. C. Fargo	Sec. 31, T. 93, R. 53	Ry	$150	310	2	20	30	No	No	Farm	No	Sand, 115; clay, 160; hard shell sand clay, 35.
E. Anderson	Sec. 13, T. 93, R. 54		180	250	2	25	40	No	No	do		
P. Peterson	Sec. 12, T. 93, R. 52		160	310	2	10	15			do		
G. Peterson			175	348	2	6	10	No		do		
M. McAlvane			140	300	2	30	35		Sand	do		
C. Olson	Sec. 28, T. 94, R. 54	Ry	155	343	2	10	20		No	do		Sand, 135; clay, 160; sandstone and clay, 40; hard rock, 8.
J. Daugherty		Ry	120	285	2	20	15		No	do		
G. W. Young	Sec. 33, T. 94, R. 54	Ry	135	285	2	75	40		Sand	do		Sand, 110; blue clay, 95; sandstone, 30; sand and clay, 50.
D. F. Morey	Sec. 35, T. 93, R. 54	Ry	140	275	2	18	15		No	do		Sand, 120; blue clay, 130; sandstone, 65; sand and clay, 50.
S. Lane	Sec. 25, T. 93, R. 54	Ry	130	245	2	30	15		No	do		
M. M. Walker	Sec. 22, T. 93, R. 54	Ry	150	295	2	15	15		No	do		Do.
W. Warfield	Sec. 26, T. 93, R. 53	Ry	125	255	2	22	15		No	do		Sand, 125; blue clay, 95; sandstone, 35.
P. W. Cross	Sec. 12, T. 93, R. 55	Ry	125	212	2	36	15		(*)	do		Sand, 145; blue clay, 160; sandstone, 7.
W. Dure	Sec. 11, T. 93, R. 54	Ry	125	290	2	25	30		No	do		Sand, 116; blue clay, 160; sandstone, 14.
A. Steffenson	Sec. 12, T. 93, R. 54	Ry	150	300	2	20	25		No	do		Sand, 120; blue clay, 160.
A. Peterson	Sec. 11, T. 93, R. 54	Ry		345	2	30	20		Muddy	do		Sand, 125; blue clay, 160; sandstone, 25; sand and clay, 35.
W. Erickson	Sec. 10, T. 93, R. 54	Ry	125	263	2	30	26		No	do		Sand, 155; blue clay, 70; sandstone, 35.
P. Lee	Sec. 12, T. 93, R. 54	Ry	150	300	2	26	25		No	do		
N. H. Buckman			350	260	2	30	15		No	do		
F. Alsagen	Sec. 8, T. 93, R. 53	Ry	125	263	2	6	20		No	do		
S. Douglas			140	315	2	40	25		No	do		
J. L. Brocton	Sec. 7, T. 93, R. 54	Ry	140	307	2	10	15		No	do		
S. Olson	Sec. 7, T. 94, R. 54	Ry	130	268	2	1	15		Muddy	do		
CLAY COUNTY.												
Vermilliont												
P. Olson, jr	Sec. 35, T. 93, R. 53	Ry	150	243	2	6	6		No	do		
P. Olson	Sec. 34, T. 93, R. 53	Ry	160	240	2	10	15		Muddy	do		
P. Adlandt	Sec. 33, T. 93, R. 53		185	311	2	60	40		No	do		
M. Peterson	Sec. 28, T. 93, R. 52		215	213	2	20	15		No	do		
G. W. Gilbert	Sec. 28, T. 93, R. 53		220	351	2	70	40		No	do		Sand, 155; blue clay, 181; water-sand rock, 16.
C. Miller	Sec. 27, T. 93, R. 53	Ry	210	270	2				No	do		Sand, 80; blue clay, 160; water-sand rock 30.

BON HOMME COUNTY.												
Scotland City	Sec. 8, T. 96, R. 58	23 A	2,050	587	4	15	0	Irregular	Sand	City	No	Black loam, 4; yellow clay, 40; b. clay, 15; w. chalk, 60; b. chalk, 60; blue shale, 80; gray sand rock, 40; blue shale, 40; quicksand, 30; b. shale, 35; quicksand, 30; lime rock, 13; water-bearing rock, 28; quartzite, 52; mechanically stopped.
Tyndall City	Sec. 6, T. 94, R. 59	Ry	2,544	636	4½	552	38	No	Trace b. clay	do	No	Light loam, 4; yel. clay, 40; blue clay, 171; shale, 100; hard rock, 7; shale, 75; sand, 60; shale, 243; water rock, 36; quartz.
A. Zeinart	Sec. 34, T. 95, R. 59	92 B	850	734	2	97	36	No	Sand	Farm and irrigation.	No	Black loam, 4; s. and g., 75; sand and rock, 38; sand, 20; s. and rock, 24; b. chalk, 12; b. clay, 4; clay and shale, 377; coal, 2; clay and shale, —; pyrites and water sand to finish.
J. P. Cooley	Sec. 19, T. 94, R. 58	176 B	1,156	578	1½	7	10	No		Stock and garden.	No	Sandy soil, 2; yel. clay, 15; b. clay, 100; chalk stone, 15.
Mat. Jensen	Sec. 20, T. 94, R. 59	200 B	700	645	1	13	45	Increased		....do	No	Black loam, 4; y. clay, 20; b. clay, 60; clay and sand, 15; white chalk, 38.
A. J. Abbott	Sec. 1, T. 93, R. 59	220 B		646	1	40	60	....do		Farm	No	Light soil, 2; yel. clay, 32; gravel, 48; chalk, 28; blue clay, —; sand, 58.
L. Snyder	Sec. 31, T. 94, R. 58	200 B		645	2	100	40		Sand	....do	No	Light soil, 2; gravel, 45; b. clay, 15; sand, 50; chalk, 100; b. clay, 288; sandstone, 40; soapstone, 40; sandstone, 35; white sand, 30.
Peter Byrnne	Sec. 5, T. 93, R. 58	180 B	1,000	665	3	250	42	Increased	....do	Farm and irrigation.	No	B. loam, 3; y. clay, 17; b. clay, 80; white chalk, 100; b. clay, —; sandstone, 46; b. clay, —; shale, —; white sand, —.
Mitchell City‡	Sec. 22, T. 103, R. 60	Ry	3,133	546	6	176	7	No	No	City	Stone reservoir.	Fine loam, 2; sandy loam, 38; b. chalk, 90; white sand, 40; b. shale, 115; pyrites, —; rock, 1; sand, 29; b. shale, 150; dry sand, 30; b. shale, 150; rock, 1; white sand rock, 25; one-inch flow, 285 feet, 15 barrels per day.
Plankinton City †												Black loam, 3; yellow clay, 223; chalk, 9; yellow clay, 303; sandstone, 5.
C. F. Hatton	Sec. 34, T. 104, R. 64	10 B	800	545	2	2½	15	No	No	Stock	No	Black loam, 30; b. clay, 200; chalk, 2; b. shale, 30; one-inch flow, 600; two-inch flow, 700; three-inch flow, 950.
White Lake City	Sec. 14, T. 103, R. 66	Ry	3,800	960	4	150	35	Increase	Sand	City	No	Black loam, 4; reddish clay, 228; quicksand, 100; gray shale, 620; sandstone, 20; flow without pressure; white sand, 30; sandstone, 8; 2-inch flow, 1 pound pressure; white sand, 20; sandstone, 4; white sand.

* When disturbed, muddy.

† See Professor Culver's report.

‡ Two wells to which I could not get access, because of action pending in courts.

Tabulated list of wells in Yankton and Bon Homme Counties—Continued.

	Location.	Elevation.	Cost.	Depth.	Size.	Flow.	Pressure.	Change.	Sediment.	Use.	Stored.	Strata.
BON HOMME CO.—con.												
Kimball City	Sec. 3, T. 103, R. 68	Ry	$4, 500	1, 068	6	325	20	No	Trace b. clay	City	No	B. loam, 4; y. clay and gravel, 18; b. clay, 10; quicksand, 5; clay and qs., 624; arenaceous and cretaceous shale, 65.
Woonsocket	Sec. 28, T. 107, R. 62	Ry	3, 820	725	6	2, 750	153	No	Sand, shale, shells, carbonized wood.	do	No	Soil, 4; yel. clay, 30; b. clay, 557; sand rock, 5; one-inch flow, 330; at 165 feet water came up to 65 feet of top.
Letcher	Sec. 15, T. 105, R. 61	Ry	1, 800	600	(*)	190	60	No		Farm stock	No	
Daniel Schmitt	Sec. 11, T. 108, R. 64			725	1	6				do	No	
Charles Wilson	Sec. 23, T. 106, R. 65											

* Estimated.

Approximate summary of flows from deep basin in division of South Dakota lying east of Missouri River and south of third standard parallel.

Number of flowing wells	65
Total flow, gallons per minute (including estimate of a few not measured)	9, 000
Average flow per minute	140

REPORT OF F. F. B. COFFIN, STATE IRRIGATION ENGINEER, FOR SOUTH DAKOTA.

In the field examination I was assigned the north part of South Dakota, lying east of the Missouri River; the north line of Brookings, Kingsbury, Sanborn, Jerauld, and Buffalo Counties being my southern boundary.

In considering the pending question, I divide this district into the three subdistricts:

SUB-DISTRICT NO. 1.

This to include the Jim River Valley, embracing the counties of Beadle, Hand, Spink, and Brown, and the eastern part of Faulk, Edmunds, and McPherson, and the western part of Marshall and Day Counties.

In subdistrict No. 1, which might also be designated as the Jim River Valley district, the conditions, topographically, hydrographically, and geologically are practically the same. In the northern part of Beadle and nearly all of Spink and Brown Counties the surface is quite level. In the western part of Beadle, nearly all of Hand, the eastern part of Faulk, Edmunds, and McPherson Counties, the surface is more rolling; and as we approach the coteaus, both on the east and on the west, the surface becomes more mammillated. In this subdistrict water can be had by means of artesian wells at practically a known depth, pressure, flow, and quality. Water for domestic purposes is generally found—

First, in springs that break out along the streams and in low places.

Second, in wells from 10 to 30 feet deep above the blue clay.

Third, in wells that go below the blue clay from 60 to 100 feet deep, where the water will rise to within 10 to 30 feet of the surface.

These same conditions are found in the other subdistricts.

In this subdistrict the geological conditions are similar. This subject will be ably treated by the geologist having charge of this branch of the investigation, and only refer to some surface indications. In the northern part of Beadle, nearly all of Spink and Brown Counties, the surface is quite level, with almost a total absence of bowlders. While in a large part of Beadle, nearly all of Hand, and that part of Faulk, Edmunds, and McPherson Counties, included in this subdistrict, bowlders are scattered over the surface, sometimes sparsely, at other places quite plentifully, many of them having one or more sides polished with visible striæ. As we approach the coteaus on the eastern and western boundaries of this subdistrict, we can trace the outlines of the lateral moraines, dimly at first, but more marked as we advance.

In the southwestern part of Beadle County there is a sort of series of concentric moraines, being both lateral and terminal, that is very beautiful.

As there are no artesian wells proper that are successful but in subdistrict No. 1, I will make a tabulated statement that will probably give all the required information:

Typical wells in subdistrict No. 1.

County.	Town.	Altitude.	Depth.	Flow per minute.	Pressure.	Bore.	Dis. to water in feet.	Cost per foot.
				Gallons.			*Feet.*	
Beadle	Huron	1,285	862	1,700	160	5⅝	725	$4.00
Hughes	Harold	1,799	1,453	150	50	......	1,435	....
Spink	Doland	1,355	947	700	150	4½	930	....
Do	Mellette	1,300	950	1,300	160	4½	935	3.40
Brown	Groton	1,333	940	800	140	4½	900	....
Do	Aberdeen (R. R. well)	1,330	940	1,000	160	4½	875	4.40
Day	Andover	1,505	1,070	250	90	......	1,065	....
Marshall	Britton	1,400	1,004	850	125	4½	976	....
Brown	Columbia	1,325	965	1,700	160	4½	928	....
McCook*	Salem	1,517	247	(*)	....	......	....	....
Aurora*	Whitelake	1,725	867	60	20	......	798	....

* Well not now flowing.

The above is a fair representation of the wells now in use. The difference in flow and in pressure is largely, if not entirely, due to the manner in which the wells are put down and finished.

When the first wells were put down but little was known about the character of the formation that had to be gone through. Where the shale has not been shut off by properly piping the bottom of the well it has caved in and damaged the flow of the well. In many cases soon after the water-bearing sandstone was struck boring ceased; as a result the flow of the well was less than a similarly located and sized well where the sandstone was penetrated deeper. The main piping should go through the shale to the sandstone. The boring should continue through the sandstone; then a perforated pipe should extend from the main pipe to the bottom of the boring to protect the bottom of the well. In every instance where that has been done the flow has been constant and regular, and the water has been clear. Where the shale has been left exposed the flow has been fitful and the water has been roily.

There has never been any accurate measurements taken of either flow or pressure before this investigation. In the water-bearing sandstone there are calcareous concretions of various sizes. Sometimes quite small, and sometimes quite large. The smaller ones are discharged by the well. Sometimes the water mains and hydrants get chocked with them. Sometimes they lodge in the nozzle of the hose and have to be removed, so that there is no mistake but they are there and they must be guarded against. If the bottom of the well is not properly constructed the shale will sometimes cave in and stop or almost stop the flow for a time, but soon large quantities of shale, in the form of mud, will be discharged by the well; sometimes with explosive force. But there are no evidences that I have been able to get that shows that any well that has been properly constructed has diminished in flow, while there is evidence that wells have increased in flow. The city well at Aberdeen, when first put down, had comparatively a small flow, about 500 gallons per minute; then great quantities of shale or mud was thrown out; then the flow increased to about double its former flow. Since then, at different times, the flow has weakened, and at one time stopped entirely; then shale or mud was thrown out, and the flow re-

sumed its original volume. With one exception all the wells that have been put down have been for water supply for the cities and towns. The citizens of the towns have sprinkled their gardens and yards with the water with beneficial results, and no injurious effect has been observed where the water was judiciously applied. Dr. Louis McLouth, president of the Agricultural College, at Brookings, says that after having made several analyses of the water from different wells, he is certain there is nothing in the water that is injurious to either the soil or to vegetation.

The present season there are several experiments being tried with a view of demonstrating the feasibility of irrigation with artesian water.

Mr. F. H. Day, of Milwaukee, Wis., has put down a well on his farm, 2½ miles southwest of Huron, for the sole purpose of demonstrating what can be done by irrigation. The well was located on the highest point on his farm. Ditches have been laid out under the direction of a civil engineer, and the water is being applied systematically. I understand about 100 acres will be irrigated this season as a test.

At Hitchcock, Beadle County, they have a little well, 3⅝ inches at the bottom, that discharges 1,240 gallons per minute, and has a pressure of 154 pounds per square inch. This little well supplies the town with water, and drives a flouring mill with three sets of rollers, and actually makes forty barrels of flour daily. The proprietor told me that the natural pressure was so steady and regular that there was absolutely not the variation of a single revolution in twenty-four hours. And yet this water is wet after doing this work, and some of it is being utilized by L. H. Hole and John H. Miller to irrigate about 70 acres in a very systematic manner, on a farm they own adjoining the town. The waste water from this well in the past few years has overflowed several tracts of land. Grain that grew on land thus overflowed the past year was exceptionally a large yield, while grain on adjoining fields not thus overflowed was a failure.

At Redfield, Spink County, the towns-people have been sprinkling their gardens the past few years, with highly beneficial results. Encouraged by this, they have laid pipes across the creek from the well to a little valley or bottom, where there is about ten acres in cultivation, for the purpose of further testing the benefits of irrigation.

At Groton, Brown County, the town authorities have set apart a plat of ground of something over four acres for a park. There is a hydrant standing at one corner of the park. The town authorities realizing that the prosperity of the town depends upon the prosperity of the farmers, have donated the use of that lot and that hydrant to a Mr. Adams and Mr. Gibbs for the purpose of making a test of irrigation. This experiment is being watched with a great deal of interest by the surrounding farmers. I trust that this act of commendable enterprise will be crowned with success.

At Frankfort they have a well that has become uncontrollable because of ignorance or carelessness or accident in putting it down. It is throwing out immense quantities of mud (shale) and sand. The situation is truly becoming alarming. But the water is wet and they are using it. A sort of company of twenty-five or thirty have "chipped in" and constructed a ditch from the well to an adjacent farm, where they are irrigating about three hundred acres as an experiment. Another case of commendable enterprise that should be rewarded by success.

The above are the principal experiments at irrigation in my district. In all the towns where they have wells they are experimenting in a small way on their gardens, and about trees. From all of which we hope to get encouragement.

At Huron the Dakota Huronite, the Huron Times, the Dakota Farmer, the Dakota Ruralist all run their presses by motors driven by the artesian well alone.

At Aberdeen, owing to the level character of the surface, it was difficult to get drainage for a sewerage system. By the advice of Benezette Williams, civil engineer of Chicago, the sewerage was conducted to the outskirts of the city into a deep deposit chamber. An artesian well was then sunk in the pump-house. From the top of the well the water is conducted through 4-inch pipes to the pumps, which raise the sewerage of the city from the deposit chamber, through a height of 23 feet, at a rate of over 2,500,000 gallons per day. All this by the direct pressure of an artesian well that cost $3,400, was sunk in less than 90 days, works automatically, requires no other attention than that of one man to oil the pumps, requires no special building, needs no repairs, and costs nothing to maintain.

There is an artesian well at St. Lawrence, Hand County, that is a failure, not because there is no water, but because the well was not properly put down. The main water supply has been shut off by injudicious piping, by getting tools fast in the well, and by general bad management. This is an evidence of the necessity of having skilled men to put down wells.

At Faulkton, Faulk County, they have a well that does not give satisfaction. The men who put down the well were inexperienced in putting down wells in the shale formation; and although they struck the water-bearing sandstone at the proper depth and found plenty of water, owing to the well being improperly finished, they have a scanty supply of water.

At Ipswich they have a well that does not give satisfaction. Here we have the same old story, incompetency in the men who put down the well. From what I could learn they struck what is known as the first flow, then went down to the second flow. By some means they got their pipe fast, and put another inside, till they reduced it to $2\frac{3}{4}$ inches at the bottom. With these impediments they have a pressure of 82 pounds to the square inch, with only 124 gallons per minute discharge. I have not the least doubt that if the well was finished to the sand rock with a $4\frac{1}{2}$-inch pipe, and a perforated pipe in the sandstone, they would have a pressure of at least 100 pounds to the square inch, and a discharge of from 800 to 1,000 gallons per minute.

At Frederick they have had a deal of trouble. There is no trouble about finding water, but in getting the well finished. What the outcome will be I can not conjecture. I inclose the report of Charles Cook, esq., that contains all the information known.

From the foregoing facts the conclusion is irresistible that water can be had in great abundance and with powerful and continuous pressure in any part of what I have designated as subdistrict No. 1, there being no evidence of any diminution in either flow or pressure, with a strong probability that it can be had in paying quantities in subdistrict No. 2. This question will be incidentally referred to when I come to treat of the water supply of the other subdistricts.

The strata of the wells in my district, so far as known, are as follows:

Railroad well at Aberdeen.

[This is the pioneer well of the State. Bored 1882.]

Drift	36	36
Blue clay	64	100
Blue shale	410	510
Limestone	20	530
Blue shale (streak of sandstone, small flow)	365	895
Sandstone	15	910
Lime, shale, and sandstone (loose and hard to drill)	30	940
Sandstone (main flow)	15	955

Stopped on hard bottom. Drilled about six hours, and made about 2 inches. The flow at first was about 500 gallons per minute; great quantities of sand was thrown out, when the flow was increased to about 1,200 gallons per minute.

Railroad well at Ashton, Spink County.

Drift	66	66
Black shale	34	100
Gray shale	300	400
Blue shale	250	650
Sandy shale (small flow; gritty)	10	660
Blue shale	135	795
Sandy shale (small flow)	35	830
Limestone (yellow lime)	30	860
Lime and shale	32	892
Pyrites of iron	8	900
Sandstone (main flow)	15	915
Blue shale (bottom)	10	925

This well was put down by the Chicago, Milwaukee and St. Paul Railway for the purpose of supplying their engines. Like most artesian wells, it did not work well in their engines and was not used. But little use has been made of the water; the well seems to be filled up some way—does not work well.

Railroad well at Andover, Day County.

[Put down in 1882.]

Drift	45	45
Blue clay	30	75
Blue shale	500	575
Limestone	15	590
Shale, with streaks of lime	480	1,070
Sandstone (main flow)	5	1,075

The altitude of this town is 1,505 feet, about 200 feet above the Jim River Valley. It is evident they stopped at the first flow. Had they gone to the next flow they doubtless would have had a strong well. The railroad company has given the use of the water to the town, and they have a very nice fire protection. The pressure and flow are moderate, but they are sufficient. I could not arrange to get the flow. The pressure is about 45 pounds.

Well at Columbia, Brown County.

[Put down in 1885.]

Yellow clay	20	20
Quicksand	8	28
Blue clay	10	38

Quicksand	30	68
Gravel	14	82
Blue clay	8	90
Quicksand	15	105
Hardpan	9	114
Gray shale	355	469
Limestone (quite hard)	2	471
Blue shale (tough)	43	514
Limestone (hard)	5	519
Blue shale	200	719
Sandstone (very hard)	2	721
Sandy shale (small flow)	30	751
Gray shale	50	801
Sandy shale (small flow)	55	856
Limestone (broken)	6	862
Sandstone (flow)	5	867
Blue shale (very tough)	20	887
Limestone and pyrites of iron	5	892
Sandstone (flow)	10	902
Lime, sand, and shale	25	927
Sandstone (main flow; good)	37	964

Stopped on hard sandstone. I found the pressure to be 160 pounds and the flow to be 1,398.60 gallons.

Well at Groton, Brown County.

[Put down in 1889.]

Soil	2	2
Yellow clay	25	27
Blue clay	35	62
Blue shale	260	322
Limestone	3	325
Gray shale	120	445
Limestone (end of 6-inch pipe)	4	449
Blue shale	430	879
Limestone (end of 4½-inch pipe)	10	889
Sandstone (perforated pipe)	33	922

I found the pressure 135 pounds and the flow 828.90 gallons per minute. This is the second well they have here. The first one is uncontrollable; the water found its way outside of the upper pipe; kept washing away until a hole over 30 feet across and 100 feet deep, and still getting larger, is the result. What the end will be nobody knows.

Artesian wells must be carefully put down.

Well at Harrold, Hughes County.

[Put down in 1888.]

Soil	2	2
Yellow clay	38	40
Blue clay	70	110
Bowlders in clay	15	125
Blue shale	155	280
Limestone	2	282
Blue shale	168	450
Gray shale (streaks of limestone)	100	550
Black shale	50	600
Black sandy shale (water rises to 75 feet of top)	140	740
Gray shale	160	900
Blue shale (at 1,000 feet, small flow)	400	1,300
Blue shale and lime streaks (3 small flows)	133	1,433
Lignite	2	1,435
Sandstone (main flow)	16	1,451
Brown shale	2	1,453

I could not visit this well, but understand the pressure is 40 pounds and the flow 150 gallons; temperature 95°. The altitude of this place is 1,799 feet, about 500 feet above the Jim River; still the water comes to the top.

Well at Britton, Marshall County.

[Put down, winter 1888 and 1889.]

Sand (pockets of coal)	90	90
Blue clay	25	115
Blue shale	293	408
Blue shale (with hard streaks)	242	650
Blue shale (tough)	175	825
Sandy shale	50	875
Limestone	5	880
Sand and shale (stratified; flow)	26	906
Shale, lime, coal, and pyrites	70	976
Sandstone (flow; shale near bottom)	28	1,004

The altitude here is probably about 1,500 feet. They evidently stopped at the first flow; yet I found the well had a pressure of 121 pounds and a flow of 601.20 gallons per minute. When flowing freely a little milky, owing to a stratum of gray shale near the bottom. Well used for water supply for the town. No irrigation; could be.

Well at Doland, Spink County.

[Put down in 1889.]

Yellow clay	12	12
Black clay	30	42
Blue shale (firm)	33	75
Blue shale (soft)	200	275
Soap stone	50	325
Blue shale	135	460
Shale, sand, and lime (small flow; clear water)	900	550
Blue shale (lime streaks)	330	880
Sandstone (main flow)	15	895
Blue shale (stopped)	2	897

I found the pressure of this well 112 pounds and the flow 710 gallons per minute, and the temperature 68°. The altitude of this place is 1,355 feet. It is evident they stopped in the first flow. At first there was a flow of only about 200 gallons. Large quantities of sand were thrown out, when the water cleared and the present flow were obtained. The indications point to a large flow and high pressure by going deeper.

Artesian well at Huron, S. Dak.

[Constructed for fire purposes. Completed September 6, 1886.]

Yellow clay	13	13
Blue clay	·76	89
Gray shale	151	240
Hard iron rock	2	242
Sand	5	247
Hard sand rock	2	249
Gray shale	175	424
Hard sand rock	10	434
Gray shale	15	449
Brown shale	101	550
Sand rock	41	591
Gray shale	101	692
Brown lime	10	702
Sand rock, white (flow; good pressure)	50	752
Hard sand rock	10	762
Sand rock, white (second flow)	40	802

The boring was continued 61 feet deeper through hard sand rock and gray lime, but was stopped at that point and the second flow utilized.

From the foregoing tables it seems that the water-bearing formation is almost a perfect level. Some allowance must be made for inaccuracy in measurement, and the altitude may not be always accurately determined. Another thing that is certainly determined is that the ranges of hills or coteaus are in no way related to the original formation. Another fact seems to be shown, the pressure of the well does not necessarily decrease as the altitude increases. At Miller, Hand County, the altitude is 1586 and the pressure is 100 pounds. At Aberdeen, at the city well, the altitude is 1330 and the pressure is 100 pounds by the same instrument. Another fact seems to be shown, the deeper we go in the same locality the greater the pressure. If water is found soon after entering the shale it will just rise to the surface, and as we descend the pressure invariably increases and with marked regularity. The temperature of the water also increases. The query naturally comes up, What is beyond?

We will now turn attention to evidences of other subterranean supply of water.

Without stopping to itemize, I will state that, as a general rule, all over my district water is generally found in what is known as surface wells, running from 10 to 30 feet deep. When water is found at this depth it is in pockets of sand or gravel. These pockets are very irregular in extent and in depth. In some places they come quite near the surface—8 or 10 feet—and underlie nearly a whole section of land. I have observed that on some farms there is never an entire failure of crops from drought. In every instance I find, upon investigation, such farms overlie one of these basins of water. The water in these basins is evidently surface water, collected from the immediate vicinity. If water is not found at this depth, boring must go down to a depth of 80 to 100 feet through the blue clay. This depth may vary from local altitudes or other conditions. When water is found at this depth, it invariably rises considerably above where it is found, frequently to within 10 or 12 feet of the surface. The water in these wells can not be lowered by ordinary pumping. These facts certainly show that the source of supply of these wells is not in the immediate vicinity. Where, then, does the water come from?

In another part of this report mention was made of ranges of hills in subdistricts Nos. 2 and 3, whose maximum altitudes were 600 or 700 feet above the adjacent plains; that the summit of these hills was composed of two separate ridges, with a wide depression between. In this depression were numerous lakes with no visible outlets. That these hills were largely composed of sand and gravel.

Now, it is evident that the water in these lakes and all the water from the rains and snows that have fallen on these hills during the centuries that have passed has found its way down in this sand and gravel, and thus on through and into the sand and gravel between the blue clay and underlying shale. Hence the pressure; hence the apparent inexhaustible supply. All along the stream and at the base of these hills, particularly the eastern base, numerous springs break out. This peculiar subterranean supply of water is more plentiful in the eastern part of my district than in the western for this reason, the eastern portion is nearer the rainy regions, and hence there is a greater supply. But it is reasonable to believe that this deficiency is amply compensated for in the almost absolute certainty that water by artesian wells can be procured in the western part sufficient to supply any deficiency.

I think it is evident that the source of supply of those little artesian wells in Grant County, in subdistrict No. 4, can be traced to the lake region in the adjacent hills, and that further investigation will demonstrate that they have a little artesian basin in which water in great abundance can be procured at a nominal cost.

Now to summarize. We have our surface wells and springs with their separate and peculiar source of supply. Then we have our deep wells under the blue clay with moderate pressure, with an entirely different source of supply. Then we find first the moderate flow in the shale; then the more powerful flow; then the third or great flow, whose power and volume are such that it has been hitched to printing presses, sewer pumps, and flouring mills with eminent satisfaction. Each and every one of these supplies seems to be separate from the others, and each could be exhausted, if such a thing were possible, without affecting the others. Then, if we should go down through the shale that is known to underlie this third flow and we should find sandstone charged with water beneath, and the rule should continue to hold good that as we go down the pressure, flow, and temperature increase, what would we have?

It seems to me that the facts evolved by this hasty examination are sufficient to warrant a more thorough examination, both theoretical and practical. It is impossible for the private individual to do it, and there are questions involved that even go beyond the reach of the State.

SUB-DISTRICT NO. 2.

This includes all that portion of my district west of sub-district No. 1, embracing the counties of Hyde, Hughes, Sully, Potter, Campbell, and the western part of Faulk, Edmunds, and McPherson.

ITS CHARACTER.

In sub-district No. 2 the topographical, hydrographical, and geological conditions are different from those in subdistrict No. 1. In this sub-district there is a range of hills called coteaus; in some places it is a sort of table-land, running north and south, with a northwestern and southeastern bearing. These hills or coteaus are the dividing ridge between the Missouri and Jim Rivers, and have a mean maximum altitude of about 700 feet above the Jim River and about 500 feet above the Missouri River. These hills are evidently not the result of an upheaval, but are of sedimentary and drift formation, and have no direct reference to the underlying shale and sandstone formation in which artesian water is found in sub-district No. 1. I do not think there is any doubt but water can be reached in this subdistrict by artesian wells, but I have doubts about its being procured in sufficient quantities to be profitable for irrigation. The wells at Highmore and Harrold are so imperfectly put down and so imperfectly finished that they are in no sense a satisfactory test as to the quantity of water that can be procured by this means. I have been unable to visit this sub-district and make a careful examination, but from what little I have seen and what I can learn I understand there is a depression running along the summit of these hills, a sort of broad valley between two lateral moraines, in which there are a number of small lakes with no visible outlet; they catch the water from the rains and melting snows. I understand that this elevated valley is sometimes several miles across, and thus serves as a great conservator of the rain and snow that falls in this section. The springs and wells that this feeds will be referred to in another part of this report.

SUB-DISTRICT No. 3.

This is to include all that portion of my district lying east of sub-district No. 1, except the county of Grant, and that portion of Roberts County lying east of the Indian reservation, embracing the counties of Deuel, Hamlin, Clark, Coddington, the eastern part of Day, Marshall, and that part of Roberts lying in the Indian reservation.

ITS CHARACTER.

In sub-district No. 3 there are conditions not found in either Nos. 1 or 2. Like sub-district No. 2 there is a range of hills or coteaus running in a north and south direction. These hills also have a depressed summit. In this elevated valley are also numerous lakes with no visible outlet. There is this difference, however: Sub-district No. 2 lies farther west and is nearer the arid regions, consequently there is less precipitation, while No. 3 lies farther east and is nearer the rainy region, consequently the lakes are larger, more numerous, and hold their water longer. The result is there is a greater supply of subterranean water in the drift in this subdistrict than in No. 2. The evidences of this will be considered in another part of this report. The mean maximum altitude of this sub-district, as near as I can learn (for I have been unable for want of time to determine that fact definitely), is about the same as in No. 2. There is another condition, or supposed condition, in this sub-district that is fundamentally different from either of the other sub-districts. There is a suspicion, and with considerable reason, that the archæan rock comes so near the surface in at least a large portion of this sub-district as to preclude the possibility of getting water by artesian wells. South of this sub-district, in Minnehaha, Moody, and Lake Counties, what is known as the Sioux quartzite crops out in vast quantities. At Salem, in McCook County, they struck the quartzite at 220 feet. I understand that at Vilas, in Miner County, they struck the quartzite at between 400 and 500 feet. At the agricultural college at Brookings, Brookings County, they bored to a depth of over 800 feet, and claimed to strike solid rock; but President McLouth informs me that there was no evidence of the fact produced. At Ortonville, Minnesota, on Big Stone Lake, granite crops out. At Milbank, Grant County, where the altitude is 1,168 feet, they struck the archæan rock at 320 feet deep; this is eleven miles west of Ortonville. This is the only evidence that has come to me that the archæan rock comes near enough to the surface to interfere with artesian wells in this sub-district.

SUB-DISTRICT NO. 4.

This includes the county of Grant and all that portion of Roberts County lying east of the Indian reservation.

In sub-district No. 4 we have conditions that are radically different from any of the other subdistricts. At Aberdeen, Brown County, we are at an altitude of 1,330 feet. As we go east, after crossing the Jim River, we find we are ascending an inclined plane. At Andover, in Day County, we are at 1,505 feet. At Webster we are at 1,871 feet. At Wau Bay we have dropped a little, and find we are at 1,842 feet. At Summit, the eastern boundary of the Indian reservation, we are at 2,030 feet. We now pitch down to Milbank, in Grant County, and find we are at 1,168 feet, in a beautiful valley. In passing through the hills stratified gravel is to be seen in the cuts and other evidences that

go to show that these hills are drift, modified drift or sedimentary formation, and not the result of an upheaval.

A hasty examination discloses these facts: We see that the eastern slope of these hills is quite abrupt. We see at the base of these hills a valley that is lower than the rest of this depressed valley. Inside and to the east of this it is skirted by a low parapet, inside of this another; these mark the lines of lateral moraines. We learn that east of here 11 or 12 miles the granite crops out. There is but little hope that artesian wells proper will ever be found here. At Milbank the archæan rock was struck at 320 feet deep; the last 20 feet was gravel charged with water, which rose to about 20 feet of the surface. There are a large number of flowing wells in this district. There are also a large number of large springs along the base of the hills. The evidence points to an abundance of water near the bed-rock, and under the shale, that rises to near the surface when tapped. Altogether there is an abundance of water in this subdistrict for every purpose when the proper means are taken to procure it. This would certainly be a splendid dairy country.

The water supply of this sub-district, its source and its application, will be more fully considered in another part of this report.

GENERAL REMARKS.*

The first question that confronts us in discussing this subject is, do we need irrigation in South Dakota?

I am aware that there is a great deal of sensitiveness among our people in reference to this question. While they are willing to admit that there are times that additional rain would be of great benefit to crops many of them are not willing to admit that irrigation is a necessity. This feeling is stronger in the eastern and southeastern part of the State than in the central and western, for the reason that they have more rain-fall.

In the first place there are droughts in all countries. In the second place, the less the mean annual rain-fall the more frequent the droughts and the more destructive they are, other conditions being equal, until there is a point reached where the drought is perpetual. The peculiar character of the soil has much to do in conserving the water, and thus resisting the drought. Proper cultivation also conserves the water. This has been so often demonstrated that it has become an axiom in agriculture. But there is a point beyond which neither culture nor condition of soil will resist drought. If these conditions can be remedied at a less cost than the profits thereof, then it is a necessity to successful farming; and that is all there is of the question. Water is absolutely necessary to vegetable life, and its application in proper quantities and at proper times is necessary to its highest development. This is irrigation. It follows then that irrigation is necessary to the highest degree of agricultural development. Why try to shun it? Why try to smother it down?

The question that now confronts us is simply this: Can we get water in sufficient quantities to supply any deficiency of rain-fall that may exist, and apply it at a cost that will justify the expense? I believe that the affirmative of the above proposition can be demonstrated, and

*As State Irrigation-Engineer of South Dakota, Major Coffin submits, without prejudice to the limitations imposed by the law, the following suggestions and conclusions.

that we have an abundant supply of subterranean water for every purpose.

I am aware that there are gentlemen whose opinions have been looked upon as authority, that maintain that irrigation by artesian wells, or by any subterranean supply of water, will be only partial or temporary; that no great permanent system of irrigation can be built up by our artesian water supply. This question can never be settled by theoretic discussion. "The more we argue, the more we disagree." The only way to settle this question is to try it. That will settle it beyond cavil. This conflict of authoritative opinions is a constant bar to the farmer, preventing him from obtaining money to improve his farm. It is an effectual embargo on his enterprise.

It must be borne in mind that we are not an arid country; that we have almost enough rain-fall to supply our wants. Just how much water will be needed can only be determined by very careful experiments.

In sub-district No. 2, I am satisfied that a great deal of water could be collected and conserved by constructing dams at the mouth of ravines and draws, thus collecting the water from rains and melting snows, and in some instances from springs. Sometimes we have heavy snows in winter, followed by rains in the spring. At such times the water in great quantities flows off into the streams and thus leaves the State, and contributes no inconsiderable part to swelling the already overflowing rivers, carrying devastation and death to the inhabitants of the valley of the Lower Mississippi. Could this water be held in reservoirs it would serve many useful purposes. Some of it would percolate through the sand and gravel, and thus re-enforce our springs and wells; some would pass off by evaporation, thus adding humidity to the atmosphere, and thus feeding vegetation. Then the surplus could be drawn off and used for irrigation, as required. Were this process carried far enough it is not unreasonable to believe that it would preclude the possibility of destitution in one section and destruction in another. In many places in this subdistrict springs of great capacity are found, as have been noted in reports already sent in. Just how many of these there are, only a careful examination will determine. All there is could doubtless be used to great benefit. Then there is the water from the wells, shallow and deep. From these the water could be raised by wind-pumps. Then we have at least a prospect of artesian wells that will be ample to supply any deficiency.

It seems too true that the evidence and indications are sufficient to indicate and justify a thorough practical demonstration of the feasibility of irrigation in this section. Should the scheme prove successful the benefit will be incalculable. It will enable the people who are here now to save their homes to which they have held on so tenaciously. It will also encourage others who have no homes to come here and improve this now idle land and build up happy, prosperous homes. I might add here that these elevated table-lands, with their rich native grasses, unsurpassed for their nutritive qualities, would make one of the finest sheep-raising countries in the world, while large portions of it is suitable for general farming. Its fertility is unsurpassed. The resources are evidently here; they only await development.

In sub-district No. 3 the surface supply of water is similar to that in sub-district No. 2, only there is more of it, owing to there being more rain-fall. What has been said about the conservation and utilization of water in sub-district No. 2, will apply here. The topography of the country is somewhat similar. In my former report I referred to the

success of artesian wells in this subdistrict as being a mooted question. I shall ever believe that artesian wells can be procured in at least a large part of this subdistrict, until a thorough test proves a failure; and possible benefits are so great that that test should be thoroughly made.

In subdistrict No. 4 we have a peculiar condition of circumstances. In my former report reference was made to the depression of this valley; also to the elevation of the hills lying west.

The construction of dams at the mouths of the ravines at the foot of the hills in this sub-district could certainly be made to conserve vast quantities of water; perhaps sufficient for all irrigation requirements in reasonable reach. There is perhaps more rain-fall in this than in either of the other sub-districts. The little artesian or flowing wells in this sub-district are a "thing of beauty." The clear, pure, cold water of these wells could be utilized for dairy purposes. Then the waste water could be collected in reservoirs and used for irrigation when needed; and in the mean time could be used for the propagation of fish. Just how many of these wells there are I have been unable to learn. How many can be had nobody knows. I understand that, like other sections of the State where deep wells are sunk, the water rises to near the surface and, as elsewhere, could be easily and cheaply procured by wind pumps. I expect to see, in the near future, this to be one of the finest dairy countries in the Northwest.

We now come to sub-district No. 1. In my former report I have given the pressure, flow, depth, and strata of these wells. There is no longer any question about water being found in this sub-district in vast quantities. There is no other artesian basin of like extent, with such powerful pressure and flow, discovered.

The formation is a difficult one to drill through, being mostly shale, with occasional streaks of sand or sandstone. These furnish water which softens the shale and increases the liability to cave in. Hence the necessity of keeping the boring well cased. This makes the sinking of the wells slow and difficult with the drills now in use. However, two reaming drills have recently been invented. One by Mr. A. E. Swan, of Andover, Day County, the other by Mr. Bowe, of Huron. The last-named drill I have seen in use in the well now being put down by J. D. Howard, at Huron. These drills promise to cheapen and facilitate the putting down of these wells. There is no question but the cost of putting down these wells will be materially lessened as we become familiar with the proper manner of putting them down and get the proper tools to perform the work.

There is another question that will have to be solved in the near future. That is, what must be used for casing the wells? It is a known fact that the water from these wells soon destroys tin vessels. From this it would follow that it is only a question of time when the iron casing of the wells will be destroyed by corrosion. It would be impossible to remove the corroded pipe and put in new. Even if the old pipe could be removed the walls of the well would cave in, and thus destroy it. If new casing is put inside of the old it will weaken and lessen the well, and in time this would destroy it, continually making it less. So it seems that, to make the wells permanent, some substance must be found to coat the pipes or to make the pipes entire that will resist the corrosive effect of the water. Some have suggested the coating of the pipes with glass, while others have suggested the making of the pipes of aluminum. He who discovers how to make a piping for these wells that will resist corrosion, so that it can be furnished at moderate

cost, will be a benefactor. It may be thought impudent or unnecessary to spring this question now, but it seems to me it is wise to prepare for possible contingencies.

It seems to me that one of the great questions, if not the question to be solved, is the method of using this water. Some would select suitable locations and put down large wells, so that the water would flow into the lake beds and small streams, and thus furnish surface water; first, for stock; second, believing that the evaporation would furnish humidity to the atmosphere, enough to increase our dews and rain-fall to a degree sufficient to supply our wants. Then there are those who would select suitable locations and put down large wells, and conduct the water as far as possible by main ditches, to be used on adjacent land when needed. And still another plan is to conduct the water through the land by means of tiling. A plan of this kind is being evolved by W. P. Butler, C. E., of Aberdeen, Brown County. I understand that he is organizing a company, and expects to make a very thorough experiment in that way.

As to the first method, that is, by filling the lake beds and small streams, I think there are grave doubts about the relief being adequate. Those who advocate this plan say that when our lake beds and small streams were full of water we had heavy dews and plenty of rain, but when the little lakes and small streams began to dry up, rain and dews began to decrease. I think the mistake here is, the effect is taken for the cause. The lakes dried up because the rain failed to furnish the needed supply. The dews disappeared, because the humidity of the atmosphere was lowered; the evaporation from the earth decreased because the rains had diminished; hence there could be no dews. The air became dry; the earth became dry. The burning rays of the sun were reflected from the parched earth; hence hot winds, that in their eager search for moisture, drank up what little there was in vegetation, and left it withered and dying. Doubtless these hot winds would be modified and their blasting effect lessened by this surface water. For it is a noticeable fact that crops that grow on the northeast side of bodies of water stand a drought better than those that grow elsewhere. So that while these bodies of water would be beneficial, I do not think they would be sufficient to avert a drought. And hence we must look to some other plan for permanent and reliable relief.

The next plan, or that of putting down large wells and serving a large tract of country, is open to some serious objections. Among the most important are such as attach to almost all corporate systems and which might in a work of this kind, prove greatly embarrassing.

The plan of Mr. Butler, of Aberdeen, is an old one, having been in operation in England for a great many years. It combines irrigation and under drainage, and is designed to equalize the moisture under all conditions. Results of this plan will be watched with great interest.

The plan that seems the most feasible, and the one that will prove the most satisfactory, is for every farmer to have his own little well, and have it so constructed that he will have absolute control of the water. In countries where they irrigate, the rule is, the water has to be carried across the country from a reservoir to the land where it is needed; and in this way a great deal of the water is lost. Here the reservoir lies under the farm and can be reached without molesting any one. By this plan the farmer can select a suitable place for his well, which will likely be a suitable place for his buildings. If it be found better to expose the water to the action of air and light before applying to the soil, he can construct his reservoir; he can here grow his own

fish; use his water when he likes, without direction or permission from any one,—something that few can say in other irrigated countries. He can use the power to run a feed-mill, corn sheller, thrashing machine, or any other purpose for which he needs power, with no extra cost whatever save the construction of a motor which any carpenter can make at slight expense. He can have his fountains; he can sprinkle his grounds; he can extinguish fires; he can defy corporations; he can feel assured of a maximum crop every year; he is dependent upon no one; he is "monarch of all he surveys." These are some of the reasonable possibilities of a proper development of our resources.

In a general way it is believed by those who have had experience in irrigation, that it would be better to collect the water in reservoirs and let it stand for a time exposed to the action of light and heat. In countries where they irrigate, the water they use is mostly collected from streams and has been fertilized by the action of air and heat; it is also charged with silt, which adds to its usefulness. The silt we can not get, but by storing in reservoirs we can get the chemical action of light and air. In a very short time it also becomes filled with innumerable animalculæ, which is no inconsiderable item. Although invisible they add greatly to the fertilizing effect of the water. The water could also be applied much better when held in large quantities.

Another advantage of this plan would be no more water would be used than would be needed. It is always prudent to be economical in using even that which seems to be inexhaustible. Improvidence is not justifiable under any circumstances.

Whatever system of irrigation that may prove to be the best, it will certainly be the cheapest, most effectual, most reliable, of any system of irrigation in existence. We shall not depend upon the amount of rain or snow that may fall on adjacent mountains. Our farmers need not be in fear of the whims or caprice of corporations. Neither will they be in fear of the breaking of dams or dikes. But with their water always in hand they are ready for any emergency.

With all these prospects before us, and with unswerving faith in their ultimate realization, it may be asked why we invoke the assistance of the General Government. In the first place there is a condition of things here that is anomalous as far as irrigation problems are concerned. While we who are familiar with local conditions are confident of results, there are those with whom we have to deal who have doubts. These doubts must be removed to insure success. A large portion of this State has been settled in the last ten years. The seasons of 1879 and 1880 were dry. When the remarkably heavy snow-fall of 1880 and 1881 went off in the spring of 1881, every low place was filled with water. In the succeeding years there were copious rain-falls. The Northwestern and Chicago and Milwaukee Railroad pushed their lines through this newly opened country.

The marvelously productive soil of this country, stimulated by timely showers, produced crops that were a continual surprise. The country settled as if by magic. Farmers were buoyant with hope; elated with enormous returns, they invested all their means. They then mortgaged their property to get more money to further improve their farms and prepare for more extensive operations. Conservative capitalists were ready and willing to advance the required money. The loans were made. For a year or two the interest and taxes were paid, then the rains began to be less frequent in their visits and shorter in their stays, until the whole United States know the story of the past winter.

It is painful to write these things, but sometimes the truth must be

told. We expect good seasons again. We have reason to expect them. It is not always dry here. We have had timely showers the present season, and prospects at present are most cheering. But if the history of the past is any criterion we shall have dry seasons again. We want to act the part of prudent men and be ready for them. Just now capitalists are a little "shy" of Dakota. "A burnt child is afraid of fire." When we tell them that if they will let us have the necessary money at a rate of interest that we can afford to pay, we can bring the water to the surface and defy droughts, they look at us in ominous silence. But may not the General Government with a comparatively small sum of money put down enough wells under the eye of an experienced engineer to demonstrate beyond doubt or cavil the feasibility of this plan? When that is done the spell is broken and the problem is solved. Without Government aid the problem may be solved by corporations. They will then put down and own the wells and rent us the water that is nature's bounty.

If it is within the province of the General Government to make donations of lands to enable a railroad company to build their lines through a new country, or to appropriate money to experiment in beet-sugar manufacture so that the makers thereof can be assured of success before they make investments; it is certainly within that province to make an appropriation to solve the problem of artesian irrigation, so that the farmers will be enabled to help themselves by borrowing money at a minimum rate of interest.

In this report I have said nothing about the south district of the east part of the State, or that part lying south of the main line of the Chicago and Northwestern Railroad and east of the Missouri River. That district is in the hands of another who will ably treat it. I might, however, be permitted to say that artesian irrigation is doubtless practicable in a large portion of this district, as they have a number of excellent wells. In a portion of that district they have additional rain-fall. Yet, I think, that advancing civilization and more scientific culture will demonstrate that it will be profitable to utilize all the water for irrigation. Then the great western part of the State is yet to examine. A careful examination by a practical eye may make wonderful disclosures.

REPORT OF HORACE BEACH, SPECIAL EXPERT.

Pursuant to my appointment as special expert, I reported to Maj. Fred. F. B. Coffin, State engineer for South Dakota, and proceeded to examine those localities in said State that are considered as most unlikely to furnish flowing artesian water:

It is well known that an upheaval has taken place in the eastern and southeastern part of the State, and that the quartzite comes to the surface at Sioux Falls, and at intervals of over 50 miles west of that place. It is largely exposed on the James River in township 101, range 58, and the effect of this upheaval extends as far north as Pipestone County in the State of Minnesota, and probably to Big Stone Lake. Wherever the Archæan rocks come to or near the surface, no flowing wells are likely to be found, as the water supplying the sands of the Cretaceous do not underlie this formation.

In the eastern part of the State there is a divide called "Coteaux des Prairies." It seems to be composed of drift, and which is found to extend to an unknown depth. The elevation of this "Coteaux" above James River is 566 feet, and above sea level, 1,845 feet. This drift lies in large hummocks or hills, with valleys intervening, in which are numerous lakes and beds of lakes. These lakes are no doubt the source of the shallow flowing wells that are found in the stratified drift, and when filled with water they help to condense the moisture and make dews and rains. These shallow flowing wells are of great importance to the settlers, and they are remarkable for their little depth, the purity and large flow of water. They are found in Grant County east of the "Coteaux," and of McCook, Hanson, Miner, and Sanborn Counties.

The following is a tabulated list of those I have investigated:

Table of shallow wells.

Name of owner.	Range.	Depth.	Flow daily.
		Feet.	*Gallons.*
Gurney Bros., No. 1	Sec. 8, t. 104, r. 56	85	123,840
Do	do	190	3,520
S. S. Pounds	Sec. 8, t. 104, r. 56	109	17,600
George Seitz	do	107	103,488
Willis Butler	do	150	32,000
Fred Butler	do	90	56,800
F. R. Santois	Sec. 8, t. 104, r. 57	125	2,840
W. H. Holmes	Sec. 12, t. 104, r. 57	125	2,840
A. C. Nopins	do	180	2,500
William Rinsleys	Sec. 7, t. 104, r. 56	125	1,600
W. P. Reeves	Sec. 7, t. 104, r. 58	127	1,920
G. O. Tripps	do	184	4,160
Paul Bachs	Sec. 7, t. 105, r. 57	150	19,200
Riley Campbells	Sec. 7, t. 105, r. 56	117	4,160

It is not known to any degree of exactness how far the Archæan rocks that are supposed to lie under the "Coteaux des Prairies" reach westward as to preclude the possibility of securing flowing artesian water.

A bore was made at Millbank, Grant County, east of the "Coteau." Granite was found at 320 feet and no flowing water was obtained. Ten miles east of this, at Ortonville, Minnesota, the granite lies at the surface.

At Albee, in township 118, Grant County, two attempts were made to bore, and granite was struck each time at 168 feet. At Brookins, Brookins County, three attempts were made to obtain artesian water. One was made by a private individual, one by the city, and one at the agricultural college at that place. In each case the boring reached 500 feet and no water found. The drillers claimed to have struck granite. At Vilas, Miner County, a well was bored by the Chicago, Milwaukee and St. Paul Railroad Company, and granite was found at 500 feet. Matthias Duclos, about 4 miles from Salem, McCook County, bored a well 350 feet without getting water, but struck a flow of inflammable gas. As far as developed it seems very uncertain about obtaining water under the "Coteaux."

I estimate that there is an area of over 20,000 square miles in South Dakota where artesian water in large quantities may be procured. The basin of the James River valley is probably the most remarkable of any yet discovered. The highest point between Huron and the river is on the "Coteaux de Missouri," at Highmore, on the line of the Northwestern Railroad. This place is 624 feet higher than the James River at Huron, and 1,908 feet above the sea-level. An artesian well was bored here to the depth of 1,552 feet, and an artesian flow was obtained of about 10 gallons a minute, which rose to about 10 feet above the surface of the ground. Every other attempt which has been made on the road to the westward has been successful, and I am of the opinion that artesian water can be found anywhere on the "Coteaux du Missouri" where the elevation above the sea-level does not exceed 1,900 feet. Archæan rocks have not been found beneath the "Coteaux du Missouri," and there is not so much drift to be observed as at the "Coteaux des Prairies." It presents more of the appearance of a denudation.

Artesian water may be obtained at Pierre, Hughes County, at a depth of from 1,200 to 1,300 feet. There is no reasonable doubt that the water-bearing sands of James Valley are a part of the Cretaceous period, and exist and pass under the Missouri River, and that wells can be bored west of that river.

I visited the following towns during this inquiry, viz: Gettysburg, Potter County, township 118, range 76, is 2,070 feet above the sea-level; an attempt was made to get artesian water, borings were made to the depth of 1,300 feet, and the work was abandoned; at Eureka, McPherson County, township 126.7, range 75, altitude 1,878, artesian water may be had here; and also at Roscoe, Edmunds County, township 123, range 70, altitude 1,820 feet, artesian water, the same result. The town of Lake Preston, Kingsbury County, township 110, range 54, lies in a depression of the Coteaux des Baines, and possesses an excellent farming country and has the following lake-beds in its vicinity:

Lakes.	Area.
	Acres.
Preston (no water at present)	7,000
Badger (no water at present)	2,000
White Wood (no water at present)	6,000
Henry	1,500
Thompson	9,000
Total	25,500

The above-named lakes are connected and now have but little water. They are the best storage reservoirs probably in South Dakota, and for experimental borings this would be the proper place to make them.

In 1883, at the request of the Hon. George B. Loring, I visited the valley of the James River and reported that I believed artesian water might be obtained anywhere in the valley, but at that time I had no idea of the almost inexhaustible supply of subterranean artesian water, which subsequent investigation has demonstrated to be there, subjected to an immense hydrostatic pressure which if developed will furnish abundant power for all economic purposes.

ANALYSIS OF DAKOTA ARTESIAN WATERS.

SOUTH DAKOTA AGRICULTURAL COLLEGE AND EXPERIMENT STATION,
Brookings, S. Dak., June 19, 1890.

DEAR SIR: I inclose herewith the report of the qualitative analysis of the samples f Artesian water from the two Dakotas, sent by the order of Prof. G. E. Culver. But four samples have been received up to date, and I have received no instructions as to whom the reports should be sent. Therefore I take the liberty to send them directly to you.

I have waited as long as possible thinking that perhaps other samples would come in, but since the time is now so short that it would be impossible to do further work in time to have the reports in Washington before the 25th instant, it seemed that further waiting would be useless.

In the reports only the substances found are reported. A searching examination has been made and although it would not be included in a qualitative analysis proper, I have taken the liberty to determine the total amount of salts dissolved in each sample.

The thought occurred to me that this datum might be of use to you in determining how much mineral ingredient would be added to the soil from a given quantity of water.

Hoping that you will be pleased with what I have done, I am, very sincerely,

JAS. H. SHEPARD.

Hon. EDWIN WILLITS,
Assistant Secretary of Agriculture, Washington, D. C.

OAKES ARTESIAN WATER.

Sample sent by A. E. Swan who states that they are still working at the pipes in the well. Water is turbid owing to the presence of suspended clay, but Mr. Swan states that the water runs clear when work is not going on in the well.

Bases.—Iron and potassium, small quantities; calcium and sodium, much; magnesium, a little.

Acids.—Silica, considerable; carbonic and sulphuric, moderate quantities; hydrochloric, much; total residue per liter, 2.810 grams.

DEVIL'S LAKE ARTESIAN WATER.

Sample sent by T. S. Benham. Water somewhat turbid.

Bases.—Iron, magnesium, and potassium, very little; calcium, small quantity; sodium, much.

Acids.—Carbonic and sulphuric, much; hydrochloric, very much; silica, small quantity; total residue per liter, 4.006 grams.

NOTE.—These two samples came from North Dakota. The waters are not alkaline to Phenol phthalein indicator.

FAULKTON ARTESIAN WATER.

Sample sent by George A. Morse. Water clear with no taste or odor.

Bases.—Iron, small quantity; calcium, small quantity; magnesium, small quantity; sodium, much; potassium, a little.

Acids.—Carbonic, sulphuric, and hydrochloric, much; silica, small quantity; total residue per liter, 2.0572 grams.

MILLER ARTESIAN WATER.

Sample sent by G. H. Carroll. Water clear without taste or odor.

Bases.—Iron and potassium, small quantities; magnesium and sodium, moderate quantities; calcium, much.

Acids.—Carbonic and sulphuric, much; hydrochloric, moderate quantities; silica, small quantity; total residue per liter, 2.090 grams.

NOTE.—The two preceding samples are from South Dakota. As expressed, the total residue may be very closely called so many parts per thousand.

CHEMICAL LABORATORY, RUSH MEDICAL COLLEGE,
Chicago, Ill., May 9, 1887.

Hon. H. J. RICE,
Huron, S. Dak.

DEAR SIR: The two specimens of water from your city's artesian well have been subjected to careful chemical analysis, with the following results. Each standing gallon of 231 cubic inches contains:

	Grains.
Silica	0.90
Sulphate of potassium	0.75
Sulphate of sodium	53.13
Sulphate of calcium	34.70
Sulphate of magnesium	5.15
Carbonate of magnesium	7.60
Carbonate of iron	0.11
Alumina	Traces.
Organic matter	Traces.
Total	102.34

The following figures show an analysis of the water which is very bad, having 47 degrees of hardness, and the enormous amount of 122 grains per gallon, U. S. A.:

	Grains.
Carbonate of lime	13.10
Sulphate of lime	20.72
Sulphate of magnesia	13.34
Chloride of sodium	13.10
Sulphate of sodium	60.70
Silica	1.25
Total solids	122.21

REPORT OF J. W. GREGORY, FIELD AGENT FOR THE MIDDLE DIVISION.

The division assigned to me consists of all of Nebraska, Kansas, Indian Territory, and Oklahoma lying west of the ninety-seventh meridian and that portion of Colorado east of the one hundred and third meridian. It contains portions of five of the grand civil divisions of the United States and has an area of 150,000 square miles.

In the prosecution of the field work in this division, since April 16, last, I have traveled 7,175 miles, prepared and mailed 2,792 letters and packages and I have received, classified, and briefed in duplicate 983 communications, requiring the handling, in the various processes of writing, addressing, inclosing, mailing, classifying, briefing, etc., of some 65,000 papers and documents. Averaging, this would amount to over 120 miles of travel for each day employed, about 50 letters per day prepared, listed, and mailed, and about 20 letters received, classified, briefed, etc., besides personal inquiries and consultations, the preparation of reports, maps, etc.

The investigation shows in this division that there are some two hundred flowing wells; I have descriptions also of one hundred and twenty wells, not flowing, regarded as artesian by reason of the water rising permanently above the level where found, though not to the surface, with data showing that the number of the latter in the division not reported in detail is undoubtedly many times greater than those described.

Incidental to the main inquiry, I have found that in this division there are hundreds of large springs, the waters of which can be utilized for irrigation, and that there are many places where the storage and conservation of large quantities of water for irrigation can be located.

Underlying this division there are vasts sheets of subterranean water in enormous quantities—near the surface and not under pressure—with well defined and established currents, which tend towards the southeast, the limits of which are unknown both as to depth and lateral extent.

It is easily accessible in many places, and by the force of quantity alone it can be cheaply led to the surface. In other places it can economically be raised by mechanical means so that this source of water supply, supplemented by the rainfall and the artesian wells, springs, and storage reservoirs, promises the ultimate reclamation of a very large amount of the land now properly classed as arid.

From replies to official inquiries received from all parts of the division the people living west of the ninety-seventh meridian recognize the importance of irrigation. They know that it is improbable that private enterprise can be induced, within any reasonable time, to make the necessary experiments to find the methods and means by which these

waters may be speedily utilized. They can only hope, then, that some plan may be devised affording reasonable aid in this direction, as there is so much at stake, in the reclamation of the arid country in which they live and in which are their homes and future interest.

In the short time allowed for the investigation much fragmentary and incomplete information was obtained, which could not be followed to results. For the same reason personal visits to various portions of my designated field were prevented.

GENERAL DUTIES.

Under orders I left Washington, D. C., April 16, 1890, for Garden City, Kans., which point was made the base of my inquiry. Commencing my tour of inquiry therefrom pursuant to a plan and itinerary approved by the special agent in charge, I proceeded via Denver and Cheyenne, through the State of Nebraska, stopping at many points to secure information and also the names of well informed persons in such counties not personally visited, to whom the circulars of inquiry could be sent. After a brief return to headquarters a similar journey was made through Oklahoma, the Indian Territory, and Fort Worth, Tex., where a consultation was had with Col. E. S. Nettleton, supervising engineer, Prof. Robert Hay, field geologist, and Mr. F. E. Roessler, division field agent for Texas.

At division headquarters as fast as communications were received giving the location of artesian waters or the addresses of such as could give detailed information in respect to the same, they were acknowledged and classified by counties and States, and properly indorsed upon the outside of the envelope. The addresses of such parties as were able to furnish further information were enrolled. By this means the accumulated information has been made easily available.

Replies were not received to about one-half of the inquiries sent out. This was due generally to procrastination, as replies still continue to be received. Others failed to respond because they thought there was no information in the matter which they could give, overlooking the fact that if there were no wells that fact was desirable to know.

THE SUB-DISTRICTS.

The territory constituting this district lies mainly between the thirty-fifth and forty-third parallels of north latitude and between the ninety-seventh and one hundred and third meridians of west longitude. For convenience and clearness in presenting the facts collected and in accordance with instructions, I have subdivided the field into eight districts.

DISTRICT NO. 1.—SUB-HUMID.

That part of the division lying east of the ninety-ninth meridian is considered as the subhumid district. It contains in Nebraska the counties of Knox, Cedar, Antelope, Pierce, Stanton, Madison, Boone, Wheeler, Greeley, Platte, Nance, Howard, Merrick, Polk, York, Hamilton, Hall, Adams, Clay, Fillmore, Thayer, Nuckolls, and Webster, and portions of Wayne, Colfax, Butler, Seward, Saline, Jefferson, Franklin, Kearney, Buffalo, Sherman, Valley, Garfield, and Holt; in Kansas it embraces the counties of Smith, Jewell, Republic, Clay, Cloud, Mitchell, Osborne, Russell, Lincoln, Ottawa, Dickinson, Saline, Ellsworth, Barton, Rice, McPherson, Harvey, Reno, Stafford, Pratt, King-

man, Sedgwick, Sumner, Harper, and Barber, and a portion each of Washington, Riley, Marion, Butler, and Cowley; all of Oklahoma except the area formerly known as the Public Land Strip; and all the Indian Territory except a strip off the west side. The purpose, in brief, was to cut off all the territory lying east of the ninety-ninth meridian as territory in which irrigation is not considered a necessity, though it would be of exceeding value because of the certainty of a crop each year and the large increase of production per acre which would be insured. It is a zone having a large population, very many prosperous cities and towns, and great agricultural interests. While there is doubtless much prejudice among its people against its being considered with reference to irrigation, on account of the mistaken idea that "it will hurt the country" to admit that artificial watering would be of any value, yet the correspondence from this district shows that there is a widely growing and intelligent realization among many of the people of the great value of irrigation as an aid to agriculture. A number who reside very close to the ninety-seventh meridian unhesitatingly declare it necessary to success in farming in their localities. The district as a whole, consists of undulating prairie land with remarkably rich soil and fine climate. It is crossed from west to east by a large number of streams, the principal ones being the Elkhorn, Loup, Platte, Republican, Solomon, Smoky Hill, Arkansas, Cimarron, and Canadian. These, with their tributaries, cover the surface of the district quite thoroughly, not only affording a most complete means of drainage, and, in the main, an abundance of water for stock, but also offering the inhabitants in many localities rich returns for their trouble and expense whenever they shall utilize the waters for purposes of irrigation. The northern end of the district seems to have fewer water courses and a dryer climate than the southern portion. There were reported to me some seventy-two flowing wells in the extreme northern part of district in Holt, Cedar, and Knox Counties, Nebraska. One correspondent, John Andres, of St. Helena, mentions three on one section and sixteen within a distance of seven miles. This is in the extreme northern part of Cedar County. C. W. Moss, of Amelia, Holt County, reports twenty wells in two townships, ranging from 55 to 80 feet in depth. Others are reported in the same vicinity, and two in Knox County, though several correspondents wrote, "No artesian wells in the county."

An area of shallow wells of very weak flow is found in the Elkhorn Valley. A pipe and point driven down 30 feet produce a small stream supposed to be fed by lakes in sand hills lying near. This report comes from Rock County, as also from Holt. I have no information that any of the artesian wells in Nebraska have been utilized for purposes of irrigation. No other flowing wells are reported in this district in Nebraska, and but five in Kansas. One of these, known as Strain's well, near Jamestown, Cloud County, flows brine, as does also a flowing well at Great Bend, Barton County. The well of Oscar Voigtlander, near the center of Ellsworth County, flows with a very slight pressure, and the water is used for stock and domestic purposes only. One other is reported at Miltonvale, Cloud County, and another in Ellsworth County, but no information was received in response to inquiries made.

The Oklahoma country and Indian Territory, for the obvious reason of the very recent settlement of the white population, present no instances as yet, of search for artesian water.

NIOBRARA DISTRICT, NO. 2.

The large portion of the division lying west of the ninety-ninth meridian, including that part in which the admitted desirability of irrigation on the eastern border gradually merges into positive and undisputed necessity for it on the west, I have subdivided according to the disposition of the natural surface drainage. The part of the division is crossed from west to east by seven distinct parallel minor hydrographic systems: The Niobrara, the Platte, the Republican, the Smoky Hill, the Arkansas, the Cimarron, and the Beaver or North Canadian. These have been made the basis of subdivision. The first of these on the north, the Niobrara district, contains the counties of Sioux, Dawes, Box-Butte, Sheridan, Cherry, Grant, Hooker, Thomas, Keya Paha, Brown, Blaine, Rock, Loup, and the western portion of Holt and Garfield. Little or no effort seems to have been made as yet in the way of prospecting for artesian water, the almost invariable answer to inquiries being that "there are no artesian wells in this part of the State." One flowing well is reported from Crawford, in Dawes County, but I have no particulars. In some parts of the district large springs are found, and the abundant underflow waters come, in some places, very near to and even above the surface. No mention is made of water rising in wells.

PLATTE DISTRICT, NO. 3.

This district in central-western Nebraska takes in the western portion of Valley, Sherman, Buffalo, and Kearney counties, the northern part of Phelps and Gosper, and the whole of the counties of Custer, Dawson, Logan, McPherson, Lincoln, Arthur, Keith, Perkins, Deuel, Cheyenne, Scott's Bluff, Banner and Kimball, with Sedgwick County, and part of Logan, in Colorado. No flowing wells are reported except one in McPherson County having a depth of but 30 feet and a slight flow. There are five non-flowing artesian wells in this district—one in Dawson County, one in Perkins, and three in Keith, though the reports indicate that a very large number of wells of this sort exist there. A great many large springs are to be found in this district, particularly in the valley of the North Platte, and underflow waters are known to exist in great quantity. The district as a whole is sparsely settled, but contains fine lands capable of supporting a large population by the aid of irrigation.

REPUBLICAN DISTRICT, NO. 4.

This includes the county drained by the Republican River and its host of tributaries. To a large extent, these lie in deep valleys whence it will be difficult to carry water to the uplands; nevertheless, the information gleaned from the reports leads me to believe that it is a region of very large irrigation possibilities. The district contains part of the counties of Franklin, Phelps and Gosper, and all of Harlan, Furnas, Frontier, Red Willow, Hayes, Hitchcock, Chase and Dundy, in Nebraska, the counties of Phillips, Yuma, and Kit Carson, with part of Arapahoe, Washington, and Logan in Colorado, and in Kansas the counties of Phillips, Norton, Decatur, Rawlins, and Cheyenne and the north two-thirds of Rooks, Graham, Sheridan, Thomas, and Sherman. But one flowing well is reported in the district, at Oberlin, Decatur County, Kansas. It has but a slight flow of mineral water and is not used. A small flow of gas escapes with the water. Wells in which the water rises above the level where found are, however, plentiful in the district, and many facts are cited by correspondents tending to show

that artesian water could be obtained at a reasonable depth. There is also an undoubtedly abundant underflow, and in the northwestern part of the district are found several of the same sort of roaring wells mentioned as found in northeastern Nebraska, having the additional peculiarity that the water in them turns to a milky color on the approach of a northwest storm.

SMOKY HILL DISTRICT NO. 5.

This district contains the southern part of the five Kansas counties; Ellis, Trego, Gove, Logan, and Wallace, and the north third or more of Rush, Ness, Lane, Scott, Wichita, and Greely Counties, Kansas, and about half of Cheyenne County, Colorado. Except in the western part, it is like District No. 4 in being traversed by valleys and streams, which are quite low compared with the general surface of the upland. There are no flowing wells in this district, but it contains numerous non-flowing wells in which the water rises permanently toward the surface and is, in the eastern part, peculiarly rich in springs. The existence of vast sheets of sub-water, not under pressure, is also abundantly proven. At Cheyenne wells, Colorado, in the western part of this district, an experimental boring for artesian water was made by the United States Government in 1883–'84 to a depth of 1,740 feet. No flow to the surface was secured, but inexhaustible sheet water was found at a depth of 280 feet. The well has never been considered in any sense a fair test for artesian water by the people of the vicinity who believe that the work was purposely hindered by unfair means and that a boring to a reasonable depth would produce a flow of water.

ARKANSAS DISTRICT, NO. 6.

In this district, which consists of a section of the valley of the Arkansas River, are included the remainder of the last seven counties named in District No. 5, the counties of Pawnee, Edwards, Hodgeman, Garfield, Finney, Kearney, and Hamilton, the greater part of Kiowa, Ford, Gray, and Stanton, and a small portion of Haskell and Grant, in Kansas; all of Prowers County, three-fourths of Kiowa, half of Bent, and two-thirds of Baca, in Colorado. Within these limits are to be found all varieties of surface from rugged breaks and sand hills to broad tracts of prairie, apparently as level to the eye as the waters of a lake. The smooth lands predominate largely and the district has exceptionally fine climate and deep, rich soil. But one area of flowing wells has been developed, namely, at and in the vicinity of Coolidge, on the western border of Hamilton County. Here five flowing wells have been secured, which are tabulated as follows:

Owner.	Depth.	Flow per minute.
	Feet.	*Gallons.*
E. H. Peck	239	45
Do	298½	120
Peck Water Works	500	90
T. B. Nolan	226	48
J. H. Borders	265	27

The well first given was the one first found. It was put down by Mr. E. H. Peck, and led to further efforts which secured the others.

It was used to supply water to a large opera house which has since been burned, thus stopping and destroying the well. The water of these wells is used for town purposes, domestic use, and for stock; but very little, if at all, for irrigation.

A flowing well at Larned, Pawnee County, sends out a large stream of water which is strongly mineral, possessing such great curative qualities that bath houses, an artificial lake, and accommodations for invalids have been provided. It flows 400 gallons per minute.

There are many of the non-flowing artesian wells in all parts of the district, and very fine springs in several localities. The district is remarkable for the number of water courses which have no outlet (the water sinking into the earth), and for the great extent and easy accessibility of its underflow waters, which in many places in the river bottoms stand continually above the surface in lakelets and pools.

CIMARRON DISTRICT, NO. 7.

This district contains the south part of the counties of Kiowa, Ford, Gray, Haskell, Grant, and Stanton, and all of Comanche, Clark, Meade, Seward, Stevens, and Morton, in Kansas, part of Baca County, Colorado, and that part of the Cimarron Valley lying within the Indian Territory, and what was formerly known as the Public Land Strip. It contains by far the most available artesian area for purposes of irrigation to be found in the middle division. There are many springs particularly in the eastern part, and large supplies of underflow waters are available. Parts of the district also possess exceptional advantages for water storage.

NORTH CANADIAN DISTRICT, NO. 8.

This consists of the country drained by the Beaver, or North Canadian, in the "Strip" and Indian Territory. It is similar in surface, soil, and climate to the last two preceding districts, but no attempts to secure artesian wells have yet been made. Like the other districts, it contains notable springs and unmeasured underflow waters.

WELLS OF A TYPICAL SUB-DISTRICT.

The instructions requiring that a tabulated and detailed report showing the wells of a "typical subdistrict" be made, the following detailed information in respect to the wells in Cimarron district No. 7, southwestern Kansas, is submitted. It is the only district in my division in which artesian water has been used for the purposes of irrigation to any extent.

The flowing wells of Meade County, according to the report of Mr. R. P. Cooper, of Meade, number not less than 150, are of the uniform bore of 2 inches, and are found within a radius of 8 miles.

One flowing well is reported from Seward County, lying next west of Meade, and two are found near the center of Morton County, at Richfield.

All the flowing wells in Meade County are in the valley of Crooked Creek.

Name and address of owner.	Altitude.	Flow per minute.	Depth.	Cost.
	Feet.	*Gallons.*	*Feet.*	
Oliver Norman, Fowler[1]	....	50	127	$28.00
B. F. Cox, Fowler:				
No. 1[2]	2,476	20	142	205.00
No. 2[3]	2,476	20	175	44.00
R. P. Cooper, Meade[4]	2,450	....	180	25.00
George Edwards, Meade:[5]				
No. 1	....	[6]45	150	15.00
No. 2	....	....	150	12.00
No. 3	....	....	184	12.00
No. 4	....	....	169	8.35
No. 5	....	....	167	10.40
S. N. Zortman, Fowler[7]	....	1	160	607.00
J. A. Martz[8]	....	66	140	....
I. P. Bowers	....	37	125	....
Public well No. 1, Richfield[9]	[10]3,200	22	670	950.00
Public well No. 2, Richfield[11]	[10]3,000	3	700	8.25

[1] Irrigates 20 acres. Mr. Norman has two other flowing wells on the same quarter section.
[2] This is the first flowing well found in the district, which accounts for the cost. Irrigates 10 or 15 acres of land. The flow has slightly decreased since the well was begun.
[3] The flow of this well has increased 25 per cent., owing to casing and clearing out of débris. It irrigates from 10 to 15 acres.
[4] Irrigates 10 acres from well reported. Has two others.
[5] Situation of No. 3 is 350 yards west of No. 1; 350 yards north of No. 3, is No. 4, and No. 5 is 550 yards southeast of No. 4. These wells are on one-quarter section; southeast quarter of section 12, township 31 south, range 28 west.
[6] Average of the five wells.
[7] Used for watering stock.
[8] This is the strongest flowing well in the district.
[9] This flowing well found west of Meade County. The pressure is given at 70 pounds per square inch, and will raise the water 125 feet above the surface of the ground. The water is used for irrigating trees and for gardening in the town of Richfield. The well is located higher than the town. Hon. W. C. Burchsled, mayor of the city, estimates that the well will irrigate 40 acres of land without reservoir. The second well, 50 feet distant, does not affect this flow.
[10] About.
[11] The slight flow of this well is accounted for by the fact that it was not completed, not being cased. The water of this well has not been analyzed and is not now used for any purpose. The flow is about the same as well No. 1 prior to casing. One correspondent states that the water of these wells is warm and insipid to the taste, but is drunk by stock.

In addition to the above flowing wells, the following names and locations in Meade County were given by Mr. Smith: W. Liebman, George Strader, F. K. Robbins, F. Sourbeer, John Foster, A. W. Kearns, W. G. Hawkins, and A. L. Craig, Fowler; Edward McDonald, E. W. Williams, D. W. Mackey, R. H. Cooper, and C. T. Martin, Spring Lake, and E. C. Gray and H. C. Gibson, Meade, one well each; George W. Killeugh, of Fowler; John Werth and Ida Werth, of Spring Lake, and I. C. Martz, of Meade, two wells each; A. B. Eliason, of Spring Lake, three; F. M. Davis, of Spring Lake, three, and G. O. Vick, of Fowler, three, two of which are described as "good" and one as "not so strong."

NON-FLOWING ARTESIAN WELLS.

To throw light upon the artesian supply in this district, the following description of non-flowing artesian wells will be found of value:

Meade County.—L. F. Gishmiller, of Joash post-office, bored a well to the depth of 113 feet; the water rose 43 feet above the level. The water is pumped for domestic purposes. The owner gives the cost of the well as $100 and states that he penetrated 40 feet of clay and gypsum in sinking the well, the remainder being "through dry sand," and that his land lies about 100 feet higher than Meade and from 100 to 150 feet above the land of G. O. Vick, Fowler, whose three flowing wells furnish an abundance of water.

E. M. Mears, West Plains post-office, has a well 170 feet deep in

which the water rose 15 feet. It cost $1.50 per foot and is used for domestic purposes; the water is clear and soft.

The Southwestern Sugar Company, of Meade, have a well 6 by 8 feet and 103 feet deep. It cost $250. Robert McHatton, of Meade, states that no log of the strata was kept. The water when found rose to nearly even with the level of the ground. The water brings up a little coarse white sand.

Mr. E. D. Smith, of Meade, says:

First a well was bored at the mill, producing a flow, but not enough for the purposes of a sugar mill, and then one was sunk with pick and shovel, 6 by 8 feet, on ground a little higher than the first; at a depth of about 100 feet the whole bottom burst up and the workmen barely escaped with their lives. The water rose to within 18 inches of the top where it remains.

A well owned by John W. Hudson, in the extreme northern part of Meade County, on a section adjoining Gray County, at an altitude of 2,630 feet, was dug and bored 113½ feet. The first water was found at 73 feet and rose 4 feet. At 113½ feet a flow of water was found in white quartz gravel, which came up freely through the pipe, carrying up quantities of the gravel. The water rose to a height of 81½ feet, or within 32 feet of the top of the ground, where it remains. A log of this well was furnished by Capt. John A. Shaw, of Montezuma, Gray County. He also gives the following particulars relating to a well 9 miles west of the foregoing:

James Holcomb's well, on the northwest quarter of section 4, township 30, range 29, in Crooked Creek Valley, was begun in 1887—bore 2 inches in diameter—struck first water at 20 feet, second water 110 feet in coarse sand. The upward flow of sand was so strong that it fastened the drill which was broken and left in the well. The water arose to within a few feet of the surface and remains so at the present time, with the drill embedded in the bottom of the well.

Clark County lies next east of Meade and presents a very similar surface. Near the southeast corner of the county an experimental well was sunk to a depth of 314 feet when work ceased and water rose in the well so that it now stands even with the surface of the ground. Mr. B. L. Stephens, postmaster at Lexington, expresses the opinion that flowing water could be had at a depth not exceeding 500 feet. Strata of rock salt were penetrated in sinking this well.

Kiowa County lies north of Comanche, at right angles with Clark. George Dewsenbury, of Mullinville, in this county, has a well 135 feet deep, made in 1886, in which the water stands 12 feet above the sheet. It is 6 miles farther north than the north line of Clark County and in a direct line east from wells described in Ford County.

Ford County.—The southwestern portion of this county lies within this subdistrict. Frederick Mueller, Wilburn, constructed a well in the southeast corner of Ford County, a little more than a mile from the Meade County line, to a depth of 150 feet, in which the water from the first stratum rose to within 4 feet of the surface, and from the second stratum to within 15 inches of the surface. He says:

Am confident we could get artesian water here, but did not have the means to bore further.

L. C. Hawes, Ford post-office, had a well bored about 9 miles from the south line of the county. It is 112 feet in depth, from which point the water rose to within 4 feet of the surface. First water was found at 31 feet. Altitude about 2,600 feet.

Gray County, immediately north of Meade, has the beginning of Crooked Creek Valley in the southern part and is a part of the same artesian area. Captain Shaw, who is now engaged in drilling for arte-

sian water in south Gray County, communicates a number of important and interesting facts. He describes the following three wells in the southern part of the county:

J. White Macomb has a well 7 miles from the Meade County line 183 feet deep, in which the first water was found at 170 feet, rising 4 feet, and 13 feet deeper the water rose to a permanent height of 30 feet.

J. D. Taylor, 9 miles from county line, 10 miles west of White's well, dug 100 feet to first water; permanent rise of water, 16 feet; elevation of surface at both, 2,700 feet.

W. H. Gamble, 3 miles from Taylor, lives in a valley of which the altitude is given as 2,570 feet. He dug 32 feet to first water and secured a permanent rise of 16 feet. In these three wells, as in the Holcomb well, the strong rise of water was found in coarse sand.

J. K. Sayre has a well 219 feet deep 6 miles east of that of J. White; writes that second water was struck at 219 feet and rose 51 feet. He states that there are several similar wells in his vicinity, in all of which the second water rises from 6 to 8 feet above the first.

Seward County.—At Liberal, in Seward County, next west of Meade, at an altitude of 2,853 feet, the Rock Island Railway Company dug a well to a depth of 485 feet; the water rose to within 125 feet of the surface and maintains that level, supplying large quantities for engines and other purposes. It is a tubular well 7 inches in diameter and furnishes about 75,000 gallons per twenty-four hours. There is no perceptible variation in the supply. The data concerning this well, including the complete log of strata following, were supplied by Hon. M. A. Low, of Topeka.

Mr. H. V. Nichols, secretary of the Southwestern Sugar Company, and superintendent of the sugar works at Liberal, says that a well was dug by the company at that place to a depth of 159 feet. At 129 feet a 10-inch hole was bored 30 feet farther. No rock was encountered. The latitude given is 2,865 feet. He adds:

> We have 5-inch piston Cook deep-well pump and could not lower the water in three weeks steady pumping. I have made diligent inquiry concerning a half dozen wells hereabouts, which, upon going about 30 feet below first sheet water (117 to 130 feet), struck a second sheet, which in every instance, rose above its level from 30 to 46 feet. We dug two wells side by side, and one is now choked with sand from below.

T. J. McDermot, of Liberal, reports a well 180 feet deep, in which the water rose 70 feet. He states:

> I dug the well 165 feet deep, 3 feet square in July, 1888. In February, 1890, I put in a tubular pump and wind-mill. There was not enough water in the well to keep the mill at work, so I got a 20-foot 4-inch pipe, let it down in the well, and drove it down 15 feet, but struck rock. Drilled through the rock 1 foot and struck water. I could not drive the pipe any further, but drilled 30 feet through clay and sand. The water flowed out through the pipe and filled the well up to the top of the pipe, and the next day 1 foot above. The pump was running all the time. I then got 2 yards of gravel, put it down through the pipe and pounded it down solid, then put the pump inside the large pipe and calked the joint. Then the water rose inside the pump some 20 feet higher. The last water is much colder and softer than the first vein.

Haskell County.—Mr. Chas. W. Woodman, of Lockport, gives the following information:

> Santa Fé has an altitude of about 3,000 feet, being higher than Liberal, in Seward County. The well in question was drilled about 1,300 feet, beginning at a 10-inch bore and gradually decreasing to 5⅝ inches. The work on the well was finally suspended for lack of funds, the water standing at about 1,200 feet in depth, or 100 feet from the surface, which is about 100 feet above the first stratum of sheet water.

Grant County.—Next west of Haskell and is traversed by the Cimarron Valley, of which the Crooked Creek Valley is a branch. Mr. E.

H. Grosclund, of Ulysses, describes a well of J. J. Rosson, near the center of the county; it is 80 feet deep and the water rises to a permanent level of 60 feet above the stratum in which it was found, and a similar well of C. W. Olmsted, in the town of Ulysses in the center of the county. Mr. Grosclund says of the Rosson well:

The water commenced to come in at 30 feet a little, not enough to amount to anything. The digging was continued until a depth of 60 feet was reached, where the well was cased as dug and a 2-inch auger was was run down in the bottom 20 feet more. At that depth it struck quicksand and dropped as far as the handles would let it go. When withdrawn the water rushed through the hole in a solid stream and inside of thirty minutes the dug portion of the well, which is 3 feet square, was filled to a height of 40 feet, being within 20 feet of the top of the ground. A similar well was bored on the premises of C. W. Olmsted, of Ulysses, in the summer of 1888. In fact, all over the county, when water is reached, if the boring is continued 30 feet, usually another stratum of water will be found, stronger in flow and better in quality, which will rise to or above the level of the first.

Morton County.—J. C. Kilbourn, Morton post-office, reports a well 190 feet deep, 3-inch bore, in which the water rose about 30 feet above the level where found. The altitude is given as about 3,000 feet. He says:

There are other wells in my locality same as my own and also dug wells the same, only water does not rise so high in them. The water in all these wells is soft and clear.

This well is very near the line between Kansas and the Public Land strip.

J. E. Carpenter, Morton post-office, describes a dug well about 12 miles distant from the last above mentioned, at an altitude of about 3,500 feet. The well is 90 feet deep, the last 15 feet being in coarse sand and gravel, and the water, when struck, rose about 4 feet in the well.

Baca County, Colorado.—West of Stanton and Morton Counties in Kansas, contains the sources of the Cimarron and is distinctly a part of the natural subdistrict under consideration. It contains no flowing wells, as no adequate effort has been made to secure artesian water, the county being newly settled.

Mr. Chas. Smith, of Springfield, states that "the water sometimes rises nearly to the surface in ordinary wells." He gives as an instance one well 92 feet deep in which the water now stands within 2 feet of the top, and his opinion is that artesian water might be had at a reasonable depth.

G. R. Gooch, of Minneapolis, describes a well 150 feet deep in the eastern part of the county and near the Cimarron, in which the water rose 119 feet, or within 31 feet of the surface, before the tools could be got out of the well. He says:

I have heard of two other wells of this sort in range 43 or 44. In one in Township 29 the water came up to 6 feet of the surface. In the other in Township 31 or 32, water came up within 17 feet of the surface. I think quite likely we are near artesian water here.

L. A. Wikoff, of Minneapolis, refers to the above-described well of Mr. Gooch and states that one about 6 miles distant is similar to it.

The altitude of the Gooch well is about 3,400 feet.

Non-flowing wells.

County.	Altitude.	From artesian center. Direction.	Distance.	Depth of wells.	Water rose.	Owner.	Remarks.
			Miles.	*Feet.*	*Feet.*		
Meade	2,575	Northwest	5	113	43	Gishmiller	
Do	2,750	Southwest	16	170	15	Mears	
Do		do	6	103	103	Sugar works	First water at 73 feet rose 4 feet.
Do	2,630	North	6	113¼	81½	Hudson	
Do		Northwest	14	110	110	Holcomb	First water at 20 feet.
Clark		East	40	314	314	Lexington	Salt water—probably.
Kiowa		Northeast	50	135	12	Dewsenbury	
Ford		do	12	150	148½	Mueller	First water rose to 4 feet of surface.
Do	2,600	do	28	112	108	Hawes	First water at 31 feet.
Gray	2,700	Northwest	17	100	16	Taylor	This was first water.
Do	2,570	do	20	32	16	Gamble	Do
Do	2,700	North	15	183	30	White	First water at 170 feet rose 4 feet.
Do	2,700	East of north	19	219	51	Sayre	
Seward	2,853	Southwest	35	485	360	Railway	
Do	2,865	do	35	159	30	Sugar Co	
Do	2,800	do	30	180	70	McDermot	
Haskell	3,000	Northwest	30	1,300	1,200	Santa Fé	
Grant	3,100	do	45	80	60	Rosson	Olmsted well similar.
Morton	3,200	South of west	70	190	30	Kilbourn	Others in same locality similar.
Do	3,500	do	75	90	4	Carpenter	Altitude probably overestimated.
Baca	3,400	West	100	150	119	Gooch	Other similar wells near.

STRATIFICATION OF WELLS.

The strata penetrated by the artesian wells of this district are reported as follows:

MEADE COUNTY.

Cox's well, No. 1.

[Reported by B. F. Cox; on northeast quarter section 5, township 31, range 27.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black, alluvial soil	3	3
Yellow clay	32	35
Blue clay	60	95
Light colored clay, changing to red	30	125
Gypsum rock	½	
Red clay mixed with gypsum	17	142
Red sand	10	152

Remarks.—The red sand in which the artesian water is found contains a slight admixture of gravel. The difference in flow of the various wells in the vicinity is caused by different elevations and different material in which water is found. If found in fine sand the flow is light, if in coarse sand and gravel the flow is strong, and the higher the surface at the well the lighter the flow.

Cox well No. 2.

[On same quarter section as No. 1.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black alluvial soil	3	3
Light or yellow clay	35	38
Blue clay	60	98
White clay, changing to red and mixed with gypsum	30	128
Red clay, with gypsum	14	142
Fine sand	2	144
Red clay, with gypsum	31	175

Remarks.—Water found immediately under last-described stratum, in red sand and gravel. The two wells are 300 feet apart; there is 1 foot difference in surface elevation and 32 feet difference in depth. The water is clear and soft.

Well reported by R. P. Cooper.

[On section 13, township 30, range 28.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black soil or sandy loam	4	4
Marl	80	84
Fire-clay	90	174
Water-bearing stratum	6	180

Well reported by Oliver Norman.

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black alluvial soil	2	2
White clay, pervious	15	17
Fire-clay, light color	50	67
Blue clay, impervious	60	127

Remarks.—The well has but 20 feet of casing in it, and that is but 2 inches in diameter. The water is found in red sand.

Well reported by S. N. Zortman.

[On section 21, township 30, range 27.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	30	30
White clay and rock	20	50
Shell stone and sand	50	100
Blue clay	57	157
Into artesian stratum	3	160

Water clear and soft.

MORTON COUNTY.

Richfield well No. 1.

[Reported by W. C. Burchsted, mayor, on section 17, township 32, range 41.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black soil	1.5	1.5
Gypsum	40	41.5
Yellow clay and sand	10	51.5
Sand	19.5	71
Blue joint clay *	1	72
Quicksand †	129	201
Blue slate	50	251
Red sandstone ‡	400	651

* Struck first water.
† Full of water, but did not rise much.
‡ Flowing water at about 637 feet.

Remarks—The flow was small until the well was cased with 2-inch casing, when it increased to its present force. The well is on top of a gypsum hill, which explains the thinness of the soil. The pressure is sufficient to raise the water 125 feet above the surface.

Richfield well No. 2.

[Also reported by Mr. Burchsted.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black soil	1	1
Gypsum	39	40
Yellow clay and sand	11	52
Sand	19	71
Blue joint clay *	1	72
Quicksand †	130	202
Blue slate	49	251
Red sandstone ‡	450	701

* Struck first water.
† Great quantity of water.
‡ Flowing water at about 637 feet.

Remarks.—This well is located about 50 feet south of well No. 1, hence the strata are very similar. The well has not yet been cased.

NON-FLOWING WELLS.

No log of the well at Lexington, Clark County, or the well described in Kiowa County, was given, nor of four out of the five reported from Meade County.

MEADE COUNTY.

Hudson well.

[Reported by Capt. John A. Shaw, on section 1, township 30, range 28.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Light soil *	2	2
Dark, coarse soil	8	10
Yellow clay	10	20
Shell lime, mixed with clay	30	50
Red, sandy clay	8	58
Sedimentary formation †	15	73
Fine sand, with water	30	103
Dark, sedimentary formation ‡	10.5	113.5

* Dug 3½ feet in diameter to a depth of 73 feet.
† First water; rose 4 feet. Bored 2-inch hole from this point.
‡ Second water.

Remarks.—There was a fine flow of water from the second sheet from white quartz gravel which was freely carried up by the water. Permanent rise of water, 81.5 feet.

FORD COUNTY.

Mueller well.

[On section 26, township 29, range 26; reported by Frederick Mueller.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black alluvial soil	2	2
Yellow clay	12	14
Fine red sand	6	20
Blue mud mixed with sand*	58	78
Whitish sand and water	3	81
Blue mud	59	140
Find sand †	10	150

* First water; rose 77 feet.
† Artesian flow rose to 15 inches of surface.

GRAY COUNTY.

Well of J. W. White.

[On section 23, township 28, range 28; reported by Capt. John A. Shaw.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Light soil	4	4
Porous yellow clay	10	14
Light potters' clay	116	130
Sandstone	2	132
Light potters' clay	36	168
Fine sand *	2	170
Light clay†	13	183

* First water; rose 4 feet. Bored from here a 2-inch hole.
† Second water at No. 7; a permanent rise of 30 feet.
Dug 3½ feet in diameter to a depth of 170 feet.

SEWARD COUNTY.

Railroad well at Liberal.

[Log received from Hon. M. A. Low.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Hard clay	6	6
Sand	35	41
Soft sandstone	22	63
Coarse sandstone	12	75
Sand	10	85
Soft sandstone	93	178
A dry crevice	2	180
Sandstone	5	185
Sand with clay mixed	80	265
Hard drift sandstone	5	270
Coarse sand, gravel, and quicksand	45	315
Sand and drift sandstone	130	445
Coarse sand and gravel	40	485

Remarks.—Water rises within 125 feet of surface, and the well will furnish 75,000 gallons of water per twenty-four hours. The coarse sand, gravel, and quicksand at Nos. 11 and 13 are full of water.

Well of T. J. McDermot.

[On section 31, township 34, range 32; reported by James K. Beauchamp, of Liberal.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Sand	4	4
Gypsum and clay	53	57
Sand and gravel	18	75
Rock	30	105
Sand and gravel	20	125
Hard rock	4	129
Sand and gravel	35	164
Fine sand*	8	172
Clay †	1	173
Sand	6	179
Rock	1	180
Coarse sand ‡	12	192
Blue clay	1	193
Coarse sand §	9	202

* Struck first water. † A stronger flow of water. ‡ Third flow of water. § Fourth flow of water.

Remarks.—Mr. Beauchamp gives the flow of this well as 15 gallons per minute, stating that the well is cased to a point 12 feet above first water, and that the water runs from the top of the casing into the dug portion of the well.

GRANT COUNTY.

Well of J. J. Rosson.

[On section 20, township 29, range 36; described by E. H. Groselund.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Sandy loam	10	10
Sandy subsoil	10	20
Yellow joint clay*	20	40
Tough, hard, impervious clay, with some thin scales of rock†	30	70
Thin layers of sand-rock with sand between	8	78
Sand‡	2	80

* Water began coming in at 30 feet, but in very small quantity.
† Dug to a depth of 60 feet.
‡ The boring-bit dropped through a thin layer of rock into water-bearing quicksand.

MORTON COUNTY.

Mrs. A. J. Little gives the following log of a well belonging to her on section 18, township 35, range 39. This is in the southeast corner of Morton County, near the line of the Public Land Strip, now a part of Oklahoma:

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black soil	3	3
Yellow clay	20	23
Gypsum rock	3	26
Fine sand and clay	4	30
Yellow clay*	50	80
Coarse sand and gravel	2	82
Yellow clay and pebbles	62	144
Gypsum rock	2	146
Clay and sand†	44	190

* Small supply of water at 45 feet. † A good supply of water.

Remarks.—This well is noted as having a sand-rock bottom and containing an abundant supply of good water, but there is no statement as to whether the water rises above the level where found or not. It is distant but 4 miles from the Kilboram well in which the water rises 30 feet, but of which no log is given.

Well of J. E. Carpenter.

[On section 15, township 33, range 42, as reported by the owner.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black alluvial soil	5	5
Impervious yellow clay	20	25
Fine sand and gravel	5	30
Whitish sandstone	20	50
Coarse sand and gravel*	15	65

*Permanent rise of water 4 feet.

Remarks.—The owner notes that "there seems to be a regular flow of water, the same as the under current in all those streams," refering to the Arkansas, Cimarron, etc.

BACA COUNTY, COLO.

Well reported by George R. Gooch.

[On section 19, township 30, range 42.]

Character of strata.	Thickness.	Depth.
	Feet.	*Feet.*
Black alluvial soil	2	2
Yellow clay	36	38
Red and white sandstone, with layers of gypsum	52	90
Red sandstone	10	100
Black slate*	50	150

*Struck a strong flow of water, which rose 119 feet.

Table of flowing wells.

District.	Flowing wells in district.	Total flow per minute.	Average flow per minute.
		Gallons.	*Gallons.*
1	90	1,350	15
6	6	730	150
7	150	3,450	23

The figures in above table are only estimates, and are based upon the very imperfect data at hand. Omitting the Larned well in district No. 6, the total flow, in above table (of the Coolidge wells), would be 330 gallons per minute, and the average 66 gallons per minute.

SPRINGS.

The facts gathered in this investigation concerning the springs of the middle division, though so fragmentary and incomplete in detail, lead me to believe that a thorough study of their location, volume, characteristics, and surroundings would prove of great value in the solution of the problem how to secure a water supply for irrigation. Not to unduly enlarge the scope of the report, however, the following brief statements are appended: In district No. 1 the largest springs de-

scribed are reported from Kansas, one of the most remarkable, the "Great Spirit Spring," in Mitchell County, being of unknown depth, the water from this and neighboring springs, and many wells in the vicinity, is unfit for irrigation, being strongly impregnated with salt and other mineral water. "Many springs" are reported from the counties of Antelope, Franklin, and Garfield (north of the Loup River), in Nebraska, from Barber, Cowley, Dickinson, Geary, Harper, Kingman, Mitchell, Osborne, Pratt, and Smith Counties, in Kansas, and from portions of the Indian Territory. "A few springs" and "small springs" are reported from numerous other localities in the district. In the Niobrara district, correspondents in Brown and Cherry Counties report many springs, and the same is true of Sheridan County and Sioux, where some of the springs are described as very large, and in the last-named county they are reported as utilized for purposes of irrigation. This is the only locality in which this use of the flow from springs is reported, though many large springs are suggested as available for irrigation. A most notable locality for springs is situated in the western part of the Platte district, centering in Cheyenne County and extending over a large part of the surrounding counties of Scott's Bluff, Banner, Kimball, and Deuel, and probably further eastward. From Mr. L. B. Carey and Mr. Lafferty, at Sidney, Nebraska, descriptions and locations of over thirty large springs were obtained, the discharge of which would, if conserved and utilized, irrigate large tracts of land. Mr. Lafferty, who is a surveyor of many years' personal acquaintance with that region, and a man of superior intelligence, states that "the waters of these springs all come forth through fissures in a white, underlying rock, where upheavals have occurred." He gives one instance where a large spring gushes forth at a point some 500 feet higher than the river, into which it immediately flows; and another where a very large volume of water is forced upward through a long fissure in the bed of a stream, making a plainly visible "ridge" in the water.

In the Republican district correspondents report many springs in Harlan County, Nebr.; in Phillips, Washington, and Yuma Counties, Colo.; Cheyenne, Rawlins, Decatur, Norton, Phillips, Rooks, Graham, and Sheridan Counties, Kans., with a few in Thomas County. That many springs would be found in this region might be expected from the configuration of the surface, and this inference is borne out by a number of correspondents who state that they are "innumerable." They are also described as "fine," one spring in Sheridan County furnishing sufficient water to run a saw-mill.

The Smoky Hill district shows similar conditions, and one would logically expect to find many fine springs, especially in the eastern part. Correspondents from that portion of the district, however, make but passing allusions to springs, while Wallace and Logan Counties seem to abound in large and valuable ones.

The same zone of springs is found extending downward across the eastern portion of the Arkansas, Cimarron, and North Canadian districts. In the first of these small springs are found in the northern part of Wichita and Scott Counties, becoming more frequent, larger, and more important in Lane, Ness, and Rush. In the next tier of counties no true springs are found in Finney County or west of it, while Garfield and Hodgeman abound with large ones, which constantly send forth big streams of water. They are probably not less numerous but smaller in size in Western Pawnee and North Ford Counties; they disappear wholly in the immediate river valley in Gray, Ford, and Edwards Counties, to appear again lower down in South Kiowa, Clark, and

Comanche Counties, eastern Meade, and on down in the Indian Territory. Many springs are also found along the North Canadian River.

Thus it is seen that an almost continuous zone of springs stretches, like the half of an Indian's bow, from the west line of Nebraska, curving downward through the Platte country, across the Republican and Smoky Hill districts, and through the eastern portion of the others. Inclosed within this arc may be found a number of deep pools, often spoken of as springs and sometimes as natural wells. The water does not flow from these—at least there is no surface stream, but they furnish unlimited supplies of water. One such is noted in Greeley County, another in Kearney, another in Seward, and others of the same sort are scattered over this region. One such pool south of the Arkansas River near the line between Kearney and Hamilton Counties is of great depth. Local report (which I have not yet been able to locate or verify) has it that a sounding of 400 feet failed to "touch bottom." Others are known to be of great depth. At least three of these pools have been formed within the past ten years by a sudden caving in of the surface of the ground, disclosing a deep body of water where there was, before, dry prairie or sand hills. One such phenomenon is reported by the Syracuse, Hamilton County (Kans.), Sentinel as occurring within the current year. At a few places along the Arkansas River chance overflows have scooped out small hollows below the level of the underflow waters and constant streams flow from these, commonly but erroneously called springs. On the western border of this region, in Baca County, Colorado, appears another area of large and fine springs which probably extends southward to a considerable distance.

COST OF WELLS.

[NOTE.—The full name and address of each of the parties mentioned in these tables will be found elsewhere in this report.]

State and county.	Owner or place.	Diameter.	Depth.	Price per foot.	Remarks.
KANSAS.			*Feet.*		
Clark	Lexington		314	$1.00	
Decatur	Oberlin	2 inches	1,000	1.00	
Do	do	2 inches	154	1.12½	Including casing.
Do	Bogue		1,100		Total cost $800.
Ellis	Weisensee		264	.75	Including casing.
Do	Conbay	6 inches	262	.75	
Do	Bowan		290	3.00	
Ellsworth	Voigtlander	2 inches	154	1.25	
Finney	Garden City	10 & 6 ins.	902		Total cost $5,000.
Do	Adams	2 inches	100	1.00	
Ford	Mueller	do	150		Total cost $35.
Gray	Sayre	do	219	.75	For first 100 feet; $1 for balance.
Do	White	3½ feet	183	1.50	Last 13 feet drilled $1.25 per foot.
Grant	Rosson		85		Dug 60 feet bored 25 feet; total cost $55.
Greeley	Ordinary Wells		100 to 200	.50	
Hamilton	Peck Water W'k's.		500		Total cost $900.
Do	Peck		298½		Do.
Do	Nolan		226	1.00	
Do	Borders		265	1.50	
Do	Koemer		355	1.00	
Harvey	Company	5⅝ inches	130	2.00	
Do	do	7⅝ inches	130	2.60	
Haskell	Santa Fé		1,300		Total cost $5,000.
Kearney	do	6 inches	97	.65	
Do	Pierce		120		Cost $300—dug.
Do	Tucker		140	.40 to .60	
Lane	Palmer	6 inches	First 100	.40	
			Second 100	.50	
Lincoln	Bartelsen	do	252	.50	
Logan	Rodgers & Sniffin		725	1.60	

COST OF WELLS—Continued.

State and county.	Owner or place.	Diameter.	Depth.	Price per foot.	Remarks.
KANSAS—con'd.			*Feet.*		
Logan	Sears		First 100 Second 100 Third 100 Fourth 100	$0.25 .50 .75 1.00	Total depth 408 feet.
Do	Miller	12 inches	84	.25	For all depths.
Meade	Hudson	3½ feet	113½		Last 40 feet bored, 2-inch bore. Total cost of well $200.
Do	Edwards No. 1	2 inches	150		Total cost $15.
Do	Edwards No. 2	do	150		Total cost $12.
Do	Edwards No. 3	do	184		Do.
Do	Edwards No. 4	do	169		Total cost $8.35.
Do	Edwards No. 5	do	167		Total cost $10.40.
Do	Cooper	do	180	.25	
Do	Norman	do	127		Total cost $25.
Do	Zortman	do	160		$8 per day.
Do	Cox No. 1	do	142	1.25	The first flowing well.
Do	Cox No 2	do	175		Total cost $44 at $7 per day.
Do	Gislemiller	do	113	.25	
Do	Mears	do	170	1.50	Including casing.
Do	Sugar Company	6 x 8 feet	103		Dug by the day; total cost, $250.
Mitchell	Tanner	2½ inches	468		Total cost $1,020.
Do	Noah	6 & 4 in	175	.40	Throughout.
Morton	Kilbourn		190	1.75	
Do	Richfield, No. 1	2 inches	670	.50	Throughout. Cost including casing, $950.
Do	Richfield, No. 2		700	.50	All the way. Well not cased. Total cost given at $825.
Ness	Ferris		25	1.00	
Norton	Stahl		113	.50	In dirt, and $1 in rock.
Osborne	Carpenter		60	.50	
Do	Viers	6 inches	100	.25	
Do	Company		500		Total cost $1,000.
Pawnee	Rush		756		Whole cost $5,000.
Phillips	Wey		514	1.00	First 100; $1.50 second 100; $2 third 100, and $2.50 per foot for fourth 100.
Do	Reeder	12 inches 6 inches	170 50		Total cost $250.
Do	Allen	4 by 4 feet 7 inches	211 139	2.50 3.00	Total depth 350 feet.
Republic	Coal Company		1,003	3.00	Total cost $3,800.
Rice	Salt Company		916	2.40	
Rooks	Budd	6 inches	235	.50	For first 100 feet; $0.75 for second 100 feet.
Do	Burroughs	7 inches	200	.25	For first 50 feet, and 10 cents per foot additional on each additional 50 feet.
Do	Hill		184	.30	
Rush	Minick	6 inches	218	1.00	
Do	do	6 & 4 in	214	.75	For 6 inch; $0.60 for four inch.
Do	Schwabb		267	1.03	Average cost of drilling.
Russell	Smith	6 inches	240	.90	
Do	Banks		970	2.50	
Saline	Fore	6 inches	94	1.00	For first 100 feet; $1.50 for second 100 feet.
Do	Carlson	6 inches	164	1.00	For first 100 feet; $1.50 for all above 100 feet.
Do	Mapes	6 inches	142	1.00	For first 100 feet; $1.50 for all above 100 feet.
Scott	Helfrick		175		Work $100; tubing, $55; total $155.
Sedgwick	Hellar	8 & 6 in	1,025	2.50	Total cost $3,400.
Seward	McDermot		180		Total cost, $300.
Stafford	Magill		51	.20	
Wallace	Osley		134	.50	
Do	Carter		140	.50	
NEBRASKA.					
Cedar	Andrews	3 & 2 in	337	.75	
Chase	Arnolds		136	.25	
Dawson	Chadwick	2 inches	106	1.50	
Deuel	Moore	do	330	1.50	
Garfield	Wright		307		Total cost, $152.
Holt	Bisbee		47	.50	Total cost, $47.
Do	Lemont		397		Total cost, $400.
Do	Shannon		395		Total cost, $400.

COST OF WELLS—Continued.

State and county.	Owner or place.	Diameter.	Depth.	Price per foot.	Remarks.
NEBRASKA—continued.			*Feet.*		
Holt	Smith		95		Total cost, $66.25.
Do	Jordan		125	$1.00	
Do	Moss		79	.75	
Do	Calkins		90		Total cost, $25.
Keith	Bertz	5 inches	375	1.00	Without reckoning cost of tubing.
Do	Fenwick	4 inches	227	1.25	Including casing and tubing.
Knox		2½ inches	603		Total cost, $1,350.
Do	Lytle Bros.	2 inches	420		Total cost, $310.
Perkins			211	1.50	
Platte	Baker		200	1.00	
Sherman	Jakob	12 inches	130	.25	Up to 100 feet; $1.50 over 100 feet.
Wayne	Wadsworth	2 inches	286	1.00	
COLORADO.					
Arapahoe	Trainor		160		Total cost, $50.
Baca	Gooch		150		Total cost, $75.
Cheyenne	Kellogg		250		Total cost, $125.
Do	Kit Carson		1,500		Total cost, $5,000.
Do	Cheyenne Wells		1,770		Total cost, $10,000.
Kiowa	Sheridan Lake	6 inches	1,280		Total cost, $4,000.
Do	Wilmutte		800		Total cost, $7,000.
Do	Towner	5 inches	367	1.00	
Otero	Van Hartingan	6 inches	47	1.25	
Phillips	Burdette		80	.25	
Prowers	Bloquin		150	1.00	
Do	Heso Ranche		309	1.50	
Yuma	Greenlee	6 inches	193	.50	Total cost, $160.
Do	Korf		202		Total cost, $150.

CONCLUSION.

That the "Great Plains Region," stretching westward from the 97th meridian to the foot-hills of the Rocky Mountains, including western Nebraska and Kansas and eastern Colorado, is possessed of beautiful surface, soil of great depth and richness, and exceptionally fine climate has long been apparent. For years considered a desert, then a vast free range for herds of cattle, it has now very largely passed into the ownership of settlers who have tried, and are trying in good faith, to make homes upon it. The average precipitation over the region is sufficient to make agriculture a success if all the moisture could be properly distributed and utilized. As it can not be done, irrigation is the one thing needful to supplement it and make success certain. It has heretofore been estimated that about 25 per cent. of the arable lands of this whole region might eventually be irrigated, and I am not unconscious that in stating that the whole region may and should eventually be reclaimed I shall probably evoke very severe criticism, perhaps ridicule. "It is written," nevertheless, and I am more than willing to abide by it, fully confident that the convincing logic of demonstrated facts will eventually justify it. I do not mean by this that every single acre will be irrigated each season. Large quantities of land in each of the most populous States are not under the plow year by year. But I do mean that over this wide expanse of rich and beautiful country a reliable system of agriculture may be established which will sustain a dense farming and manufacturing population, that the flocks and herds of domestic animals will far outnumber the buffalo, the antelope, the coyotes, and prairie dogs which they replace, that a hundred blades of grass will grow where one grew before and millions of trees on soil which never had known the shade

of a bough. It will be a work of time, much more time than ought to be consumed in the process of change, and nothing but intelligent system and beginning right and early will accomplish results within any reasonable time. Many settlers have given up the fight, and such are the difficulties to be mastered many others will inevitably succumb. Those who persist and will make intelligent use of facts, regardless of preconceived ideas and alleged scientific or other theories, will reap a rich reward. In the solution of the problem of irrigation for the middle division, artesian wells will be a small factor; springs, both for the water they supply and for what they indicate, will be of much value. The storage and conservation of storm and other waters by damming draws and ravines, for which this division offers great and valuable facilities, will be of very great importance, but more than equal to all other means combined will be the utilization of the vast stores of sheet water which underlie the plains.

Incidental to the artesian wells' investigation, and without expense to the Government, I have accumulated many valuable facts regarding the underflow waters in addition to what had been learned by previous personal investigation. These will gladly be placed at the disposal of the special agent in charge at any time.

TABLES OF COMPARATIVE AVERAGE VALUES OF AGRICULTURAL LANDS WITH AND WITHOUT IRRIGATION.

Among the queries in the artesian wells inquiry blanks were the following:

What is the value of farm land in your vicinity?
What would be the value of the land if it were provided with means for irrigation?

In tabulating the figures given in answer to these queries, the replies received from the subhumid area are given separately from those of the other districts, which are tabulated together. This shows the estimated increment of value added by irrigation to lands which are regarded as at least fair farming lands without it, and also the estimated increase in the average value of lands grading from subhumid to arid. As will be noted, many of the estimates are dual; accordingly columns of averages are given, and also a column showing the percentage of increase in value—these supplied by the agent. The estimates of value are the figures given by the correspondents named.

In the sub-humid area.

Name of correspondent.	Post-office.	County.	State.	Value of farm lands per acre. Without irrigation. Estimated value.	Without irrigation. Average.	With irrigation. Estimated value.	With irrigation. Average.	Per cent. of increase in value.
A. H. Wright	Willow Springs	Garfield	Nebraska	$5.00	$5.00	$5.00	$5.00	
C. W. Moss	Amelia	Holt	....do	1.00–8.00	4.50			
N. B. Bisbee	Chambers	....do	....do	20.00	20.00	20.00	20.00	
C. W. Lemont	Mineola	....do	....do	4.00–8.00	6.00	15.00–25.00	20.00	233
George Shannon	....do	....do	....do	5.00	5.00	20.00	20.00	300
Willie Calkins	Harold	....do	....do	5.00–10.00	7.50			
Lytle Brothers	Herrick	Knox	....do	5.00–20.00	12.50	(*)	25.00	100
L. J. Cramer	Columbus	Platte	....do	20.00–40.00	30.00	(*)	60.00	100
William Jakob	Hayestown	Sherman	....do	20.00	20.00			
R. Wadsworth	Wayne	Wayne	....do	12.00–40.00	26.00			
J. L. Nygaand	Herman	Lincoln	Kansas	10.00	10.00	50.00	50.00	400
W. H. Noah	Walnut Grove	Mitchell	....do	10.00–20.00	15.00	25.00–50.00	37.50	150
N. B. Carpenter	Pleasant Plains	Osborne	....do	1.25	1.25	50.00	50.00	3,900
E. B. Roadhouse	Osborne	....do	....do	10.00–20.00	15.00	100.00	100.00	566
Sidney Viers	Alton	....do	....do	5.00	5.00	50.00	50.00	900
G. F. Ruede	Kill Creek	....do	....do	8.00–25.00	16.50	(*)	33.00	100
Frank Hatch	Osborne	....do	....do	10.00–25.00	17.50	40.00–75.00	57.50	235
W. P. Binford	Pratt	Pratt	....do	10.00	10.00	30.00	30.00	200
P. P. Trueheart	Sterling	Rice	....do	20.00–40.00	30.00	(†)	37.50	25
W. C. Fore	Assaria	Saline	....do	25.00–50.00	37.50	(*)	75.00	100
A. N. Case	Bavaria	....do	....do	10.00–35.00	22.50	75.00	75.00	233
S. J. Carlson	Wonderly	....do	....do	15.00	15.00	35.09	35.00	133
——— Hall	....do	....do	....do	10.00–15.00	12.50	40.00–50.00	45.00	260
——— Mapes	....do	....do	....do	8.00	8.00	40.00	40.00	400
Martin Hellar	Wichita	Sedgwick	....do	16.00–50.00	33.00	75.00	75.00	127
C. F. Magill	Stafford	Stafford	....do	10.00–20.00	15.00	(*)	30.00	100
Average					15.40		44.50	189

* Double. † 25 per cent.

Of the foregoing, the first named alone stated that irrigation would "make no difference" in the value of his land, which, as may be noted, he values at $5 per acre. The third gave the same value, $20 per acre, throughout. A number of others gave only the present value of their lands, without giving any estimate of what would be the value if provided with the means of irrigation, or expressing any opinion as to its desirability, while many others stated that irrigation would enhance the value of their lands "very largely" without giving any estimate either of present or probable value. For further comment on the above table see notes following.

In the Semi-arid area.

Name of correspondent.	Post-office.	County.	State.	Value of farm lands per acre.				Per cent. of increase in value.
				Without irrigation.		With irrigation.		
				Estimated value.	Average.	Estimated value.	Average.	
W. G. Arnolds	Lamar	Chase	Nebraska	$10.00	$10.00	$50.00	$50.00	400
S. W. Yeast	Valentine	Cherry	do	10.00	10.00	20.00	20.00	100
Robert Chadwick	Lewellen	Dawson	do	20.00	20.00			
Henry Moore	Big Spring	Deuel	do	16.00	16.00	40.00	40.00	150
L. W. Young	Wilsonville	Furnas	do	5.00–10.00	7.50	15.00–25.00	20.00	166
S. P. Gibson	Mineola	Holt	do	5.00	5.00	25.00	25.00	400
Henry Bertz	Big Spring	Keith	do	6.00	6.00	25.00–30.00	27.50	358
C. H. Brown	Ogallala	do	do	10.00	10.00	30.00	30.00	200
G. W. Pennybacker	Grant	Perkins	do	10.00	10.00	50.00	50.00	400
J. H. Davenport	Newport	Rock	do	8.00	8.00			
B. L. Stephens	Lexington	Clark	Kansas	2.00–10.00	6.00	10.00–50.00	30.00	400
J. R. Morton	Protection	Comanche	do	5.00	5.00			
Charles E. French	Nescatunga	do	do	5.00	5.00	10.00	10.00	100
A. J. Mowry	Lucerne	Decatur	do	5.00	5.00	40.00	40.00	700
C. C. Reynolds	Oberlin	do	do	5.00–30.00	17.50	50.00–500.00	275.00	1,471
John Weisensee	Walker	Ellis	do	10.00	10.00	25.00	25.00	150
William Crawford	do	do	do	10.00	10.00	50.00	50.00	400
Philip Coubay	Hays City	do	do	5.00	5.00	50.00	50.00	900
E. C. Adams	Terryton	Finney	do	1.25	1.25	50.00	50.00	3,900
J. F. Gondy	Wilburn	Ford	do	5.00	5.00	15.00	15.00	200
Fred. Mueller	do	do	do	1.25	1.25	40.00	40.00	3,100
C. F. Hoadley	Loyal	Garfield	do	5.00	5.00	20.00	20.00	300
E. H. Grosclund	Ulysses	Grant	do	5.00	5.00			
John W. Hudson	Hess	Gray	do	2.00	2.00	60.00–70.00	65.00	3,150
Capt. J. A. Shaw	Montezuma	do	do	5.00	5.00	25.00–75.00	50.00	900
J. H. Sayre	Ensign	do	do	5.00	5.00	30.00	30.00	500
Eugene Tillieux	Tribune	Greeley	do	3.00	3.00	50.00	50.00	1,566
William McGlashen	Horace	do	do	1.25	1.25	15.00–20.00	17.50	1,300
E. H. Peck	Coolidge	Hamilton	do	5.00	5.00	15.00–20.00	17.50	250
J. H. Borders	do	do	do			100.00	100.00	
M. Finity	do	do	do	3.00	3.00	15.00	15.00	400
A. W. Koemer	Syracuse	do	do	4.00	4.00	12.00	12.00	200
Charles W. Woodman	Lockport	Haskell	do	5.00	5.00	25.00	25.00	400
A. B. Tucker	Kearney	Kearney	do	10.00	10.00	30.00	30.00	200
F. B. Noble	Glick	Kiowa	do	5.00–10.00	7.50	25.00–50.00	37.50	400
John B. Ennis	Oakley	Logan	do	4.00–15.00	9.50	30.00–50.00	40.00	321
J. Milton Sears	Elkader	do	do	5.00	5.00	25.00–40.00	32.50	550

In the Semi-arid area—Continued.

Name of correspondent.	Post-office.	County.	State.	Value of farm lands per acre.				Per cent. of increase in value.
				Without irrigation.		With irrigation.		
				Estimated value.	Average.	Estimated value.	Average.	
H. L. Benson	Elkader	Logan	Kansas	2.00– 4.00	3.00	25.00– 50.00	37.50	1,150
George W. Keys	Oberlin	do	do	5.00–12.50	8.75	25.00	25.00	185
—— Miller	Winona	do	do	2.50–15.00	8.75	15.00– 25.00	20.00	130
Robert McHatton	Meade	Meade	do	5.00	5.00	10.00– 30.00	20.00	300
E. M. Means	West Plains	do	do	2.00	2.00	25.00	25.00	1,150
S. N. Zortman	Fowler	do	do	1.25	1.25	10.00– 50.00	30.00	2,300
R. P. Cooper	Meade	do	do	5.00	5.00	50.00	50.00	900
B. F Cox	do	do	do	3.00	3.00	30.00– 50.00	40.00	1,233
Mrs. A. J. Little	Cess	Morton	do	5.00	5.00	20.00	20.00	300
J. C. Kilbourn	Morton	do	do	1.25	1.25	25.00– 40.00	32.50	2,500
J. E. Carpenter	do	do	do	5.00	5.00	50.00	50.00	900
W. C. Burchsted	Richfield	do	do	2.50– 6.00	4.25	(§)	21.25	400
Robert A. King	do	do	do	....	....	25.00– 40.00	32.50	....
J. W. McClain	Tuloga	do	do	.50	.50	25.00– 30.00	27.50	5,400
L. E. Knowles	Ness City	Ness	do	5.00–10.00	7.50	30.00– 50.00	40.00	433
E. R. Ferris	Beeler	do	do	1.25	1.25	30.00	30.00	2,300
Henry Stahl	Norton	Norton	do	10.00–15.00	12.50	....	....	....
Newton Hill	Clayton	do	do	5.00	5.00	....	....	....
W. M. Zachariah	Larned	Pawnee	do	3.00– 5.00	4.00	30.00– 50.00	40.00	900
H. C. Wey	Kirwin	Phillips	do	10.00–12.50	11.25	25.00– 40.00	32.50	188
W. A. Reeder	Logan	do	do	5.00	5.00	50.00 -100.00	75.00	1,400
J. H. Allen	do	do	do	4.00– 6.00	5.00	40.00– 50.00	45.00	800
B. M. Tobias	Ludell	Rawlins	do	5.00– 7.00	6.00	15.00	15.00	150
J. V. Burroughs	Zurich	do	do	20.00	20.00	50.00	50.00	150
F. P. Hill	Stockton	do	do	5.00–10.00	7.50	10.00– 20.00	15.00	100
J. H. Hoole	Gorham	Russell	do	10.00	10.00	25.00	25.00	150
G. Schwabb	do	do	do	8.00–10.00	9.00	100.00	100.00	1,011
W. R. Newman	do	do	do	8.00	8.00	30.00	30.00	275
J. W. Toney	Lippard	do	do	10.00	10.00	30.00	30.00	200
H. V. Nicholls	Liberal	Seward	do	5.00–30.00	17.50	50.00	50.00	186
L. E. Keiffer	do	do	do	5.00–15.00	10.00	50.00	50.00	400
J. K. Beauchamp	do	do	do	4.00	4.00	50.00	50.00	1,150
J. M. Helfrick	Pence	Scott	do	1.25	1.25	100.00	100.00	7,900
I. N. Pence	Sheldon	Sheridan	do	3.00	3.00	10.00	10.00	233
A. B. Thompson		Sherman	do	3.00– 5.00	4.00	25.00	25.00	525
A. Harris	Edson	do	do	5.00	5.00	30.00	30.00	500
A. A. Hiatt	Lamborn	do	do	3.00–60.00	4.50	30.00	30.00	566

J. K. Perry	Seguin	Sherman	Kansas	5.00–10.00	7.50	40.00–100.00	70.00	833
D. L. Spitzer	Menlo	do	do	5.00–10.00	7.50	25.00– 30.00	27.50	266
John Maxwell	do	do	do	10.00	10.00	40.00	40.00	300
Ben. C. Rich	Wa Keeney	Trego	do	5.00–10.00	7.50	40.00–100.00	70.00	833
John Osley	Weskan	Wallace	do	5.00– 6.50	5.75	20.00– 35.00	27.50	378
Ed. Carter	do	do	do	5.00– 6.00	5.50	25.00	25.00	354
W. E. Babcock	Leoti	Wichita	do	3.00	3.00	6.00– 10.00	8.00	266
James Trainer	Thurman	Arapahoe	Colorado	1.25	1.25	40.00	40.00	3,100
B. F. Rawalt	Friend	do	do	5.00	5.00	40.00	40.00	700
R. H. Sheets	Cheyenne Wells	Cheyenne	do	2.50	2.50	25.00	25.00	900
H. M. Kellogg	do	do	do	1.25	1.25	25.00	25.00	1,900
C. H. Huston	Towner	Kiowa	do	6.00	6.00	25.00	25.00	316
C. S. Wilmuth	Water Valley	do	do	2.50	2.50	17.50– 25.00	18.75	650
H. A. Jones	Sheridan Lake	do	do	2.00	2.00	10.00– 40.00	25.00	1,150
A. L. Burdette	Wakeman	Phillips	do	1.25	1.25	25.00	25.00	1,900
A. L. Cauble	do	do	do	3.00–10.00	6.50	20.00– 35.00	27.50	350
Alex. Ludlum	Ludlum	Yuma	do	20.00	20.00	100.00	100.00	400
Average					6.32		41.05	550

Even in the same or adjacent localities the wide range in values of lands similar in character and surrounding, as given in the above tables, is notable, but characteristic. Ask the same questions at one time of any ten men in a given locality, and the answers will show as wide variation; their estimates being largely affected by individual temperament and surrounding conditions. The averages, therefore, may be taken as a fair estimate of the value of the lands under consideration. The first table shows that, according to the opinions of the people concerned, while their land averages well for agricultural purposes, it would be nearly trebled in value if provided with the means of irrigation, while the average of the lands of the semi-arid districts (the eastern part of which is just as good as the adjacent land classed as subhumid), according to the estimates of the people themselves, would be rendered worth six and one-half times as much as now if an adequate water supply for irrigation could be had.

It very soon became apparent, however, that while the replies to the question as to the present value of land were undoubtedly based upon actual knowledge of facts, a very large majority of those giving an estimate of what the same land would be worth under irrigation were without any personal knowledge of the value of irrigation, hence their estimates were only mere guesses. The instance has already been mentioned of the man whose land is worth but $5 per acre by his own estimate, yet who states that irrigation wonld not increase its value; and a glance at the columns of both tables will show many estimates of irrigated lands at $25 per acre and under. As an estimate—being in the nature of expert testimony—can only be of value when based upon actual knowledge and personal experience, letters were addressed to a number of gentlemen in Kansas, Colorado, and California, whose practical experience in the cultivation of land under irrigation enables them to judge of its actual value and whose character and standing insures conservative and reliable estimates. Of each the following question was asked:

What is, or will be, the actual value of good agricultural land in your region when assured an adequate and permanent supply of water for irrigation? that is, upon what sum per acre will such land net legal interest if properly cultivated?

Replies to this question were received from sixteen persons, and the same are given herewith, some contenting themselves with giving simply the estimate of value, while others made more extended replies. They will be found of interest and value.

C. H. Longstreth, of Lakin, Kearney County, Kans., has been engaged in farming by irrigation for the past eight years. He was for some years employed by the Atchison, Topeka, and Santa Fé Railway Company as forester for that corporation, and is a practical and conservative man. His reply is: "It is worth $100 per acre. 'Properly cultivated' means a great deal. With irrigation assured I expect to make my farm far exceed the value of $100 per acre, if I live.'"

Capt. John Ballinger, Deerfield, Kearney County, who has had several years' experience in growing crops by irrigation, says: "Such land is worth $50 per acre. I have 75 acres that will pay 12 per cent. on a valuation of $50 or $60 per acre this year, besides all expenses of irrigation and cultivation."

J. V. Carter, Garden City, Finney County, has resided there for a number of years, and says: "Such land is worth $50 per acre. For gardening purposes, in small tracts, it is worth much more."

Squire Worrell, of Garden City, who had large experience in irrigation in California, was one of the first to practice it in the State of Kan-

sas, writes: "If cultivated either in fruits or alfalfa it is worth $100 per acre; if in general crops, $50 per acre."

James Craig, was one of the first to engage in farming by irrigation near Garden City. He took an active part in the construction of irrigating canals and is as conservative as he is successful. In answer to the first part of the question he says: "Fifty dollars per acre."

W. H. Fant, of Garden City, says: "In my candid judgment it will net 10 per cent. interest on a valuation of $250 per acre. I am farming 160 acres 2 miles north of Garden City, and from past experience I am thoroughly convinced that, with a constant supply of water, I can make $25 to $30 per acre clear of all expenses on the raising of the alfalfa crop alone. Our land, having a constant supply of water, also yields an average of 30 to 40 bushels of wheat per acre."

One thing which will strike the careful observer in studying the figures given is, that only those who have been long engaged in farming by irrigation and those who have the courage to base their estimates of value upon unquestioned results place the value of irrigated land as high as it deserves. Rarely does the party estimating the value of such land give due consideration to the important fact that it renders a good crop certain each year. The removal of the element of uncertainty, so destructive to the farmer's calculations and peace of mind, is certainly a matter of no small importance. When the industrious agriculturist can count with certainty upon a return for his labor, he is in a fair way to become "an independent farmer," if he was not so before. Then the difference of value between irrigated and non-irrigated lands is so great, that the fear of being dubbed a "boomer" or accused of being "wild" often prevents a free expression of opinion by those whose personal experience fits them to give a just estimate. Take, for example, the last four persons named in the last foregoing table, who estimate the value of irrigated land at $50 per acre. From a personal knowledge of the men and their operations the writer is confident that if each was asked whether the net return from his land last year amounted to but $5 per acre, each would state without a moment's hesitation that it was more than double that amount. In the vicinity of Garden City last season, to the writer's personal knowledge, several persons sold $40 worth of alfalfa seed per acre and had three cuttings of hay--or two of hay and one of "alfalfa straw," so called—making from 4 to 6 tons per acre of excellent feed, in addition to the seed sold. Rev. J. T. Pearce, of the same locality, has netted over $100 per acre from sweet-potatoes for five years in succession, and others have done as well for three years or more; and similar facts might be given as to other kinds of crops. Yet, "back east, where we all came from," good farming land is worth $35 to $60 per acre. This is proven to be good farm land; hence, when the question of value is sprung, the reply is: "About $50 per acre." The farmer may know that he has netted $10, $15, or $25 per acre, or more, above cost of production, taxes, etc., yet but few will have the courage of their knowledge to claim that their land is worth $100, $150, or $250 per acre. The best results from irrigated lands are obtained by those who farm small holdings. As Mr. Van Dyke has well stated, the man who thoroughly farms ten acres by the help of irrigation is sure of a good support for his family. On large bodies of land—speculative farming—the returns are not so large, which is a most fortunate fact.

Almost any Colorado man who is acquainted with irrigated lands if interrogated as to their value will unhesitatingly answer off-hand, "A hundred dollars an acre." While believing this the minimum of

conservatism (always considering that a certain and adequate water supply is coupled with industry and experience), if we take this valuation as the standard of value for irrigated lands, although it is less than the smaller average in the tabulated statement, it will be seen that the statements heretofore made that irrigation increases the productive capacity of land five to fifteen fold is more than corroborated by the estimates of value of irrigated lands supplied in the first two tables. The average of estimated values in the subhumid area being about $15 per acre, and in the semi-arid districts about $6 per acre. If, then, we consider that in the subhumid area there are about 50,000 square miles and in the six semi-arid districts a total of about 100,000 square miles, of land which is justly described by the inhabitants as naturally rich in soil and beautiful as to surface—if only 25 per cent. of this area should be brought under irrigation, it would increase the sum total of the national wealth by the enormous amount of more than $8,700,000,000. What is of vastly greater importance is the fact that the speedy provision of the means of irrigation signifies the achievement of comfortable, independent homes, the means of subsistence, the difference between most gratifying success and most lamentable failure to thousand of worthy citizens of the United States.

REPORT OF L. G. CARPENTER, DIVISION FIELD AGENT FOR COLORADO.

The region assigned to me as field agent being that portion of Colorado from the one hundred and third meridian to the foothills, as also that part of New Mexico east of the foot-hills of the Rocky Mountains, and it includes a territory about which there can be no difference of opinion regarding the necessity of irrigation and for an additional supply of water.

The water supply of this region is scanty. The only living streams have their source in the mountains and are fed by the snow-fields of the high altitudes. Not a tributary flows into the Platte from the right on the plains side in Colorado after leaving the mountains, and none from the plains feed either the Platte or the Arkansas. The streams of the plains are streams only after storms, when they may be roaring torrents. They disappear as suddenly as they rise, and for the greater part of the year their visible bed is as dry as the rest of the prairie.

The irrigated region is therefore limited to the country near the mountains, and they are supplied with the mountain streams, and to the narrow strips of land extending into the plains along the banks of the larger streams. But the whole region east of the foot-hills is as capable of raising crops as that at present cultivated. It lacks the single element of moisture. The area of this plain in Colorado is not far from 30,000,000 acres, of which about 1,620,000 acres, or 5 per cent., are "under ditch," *i. e.*, so situated that water can be furnished to the land from some existing ditch.

All of this land is not at present "under ditch." In the area under consideration there is probably not over one-half, and the pressing need of a more abundant water supply is demanded. This being the case, the extension which may come from the methods of saving, taught by experience—saving in distribution from the streams, in distribution from canals, from better practice in irrigating—from the storage of waste water, will not materially affect the status of this vast plain.

The supply must be from other sources than those which supply the present irrigated districts, and consequently the importance of investigation into the resources in the artesian or underground water supply of these regions can not be overestimated.

The foregoing remarks are intended to apply especially to Colorado; they apply also with but little change to New Mexico. That Territory does not have the extensive area of unbroken plains that Colorado possesses. It is broken with numerous mountains scattered through the Territory. It is, so far as surface appearances, in much greater need of water than Colorado, and all that may be said with reference to the desirability of investigation will there apply with greater force.

In this report Colorado and New Mexico will each be considered separately.

ARTESIAN WELLS IN COLORADO.

The first attempt at finding artesian water within the limits of Colorado seems to have been made in 1870, at Kit Carson, in eastern Colorado, by General W. J. Palmer, then manager of construction for the Kansas Pacific Railway. No water was found. The boring was carried to 1,500 feet.

In 1874 an attempt was made on the high ground at the old cemetery east of Denver. The pressure was not sufficient to bring the water to the surface at that point, and the well was abandoned at 795 feet.

The first flowing well in the State was struck at Pueblo. O. E. Clark, who had come from the oil regions of Pennsylvania, was sinking a well in the bottoms, on the south side of the Rio Grande River, at Pueblo, and obtained flowing water from a depth of 1,166 feet, January 1, 1880. Another well was sunk on the Mesa, west of Clark's, in 1880 or 1881.

This ended the attempts until the accidental discovery of water by R. R. McCormick, of Denver, while boring for coal in North Denver, March, 1883. The water was characterized by extreme purity, and was present in such quantity as to force him to stop his boring. Considerable attention was attracted by this discovery, and soon various enterprising citizens of Denver sank wells, all successful. The following year saw a greater development, and since that time a large number of well-drillers have been busy in the Denver basin. Nearly every large building and hotel in Denver has one, and a large proportion of the farmers within a limited distance of the Platte River.

The success of the Denver attempts led the town of Greeley to make an effort to discover artesian water and starting their well in the fall of 1883 they struck water, but at a much lower depth than the Denver supply. Water comes from 1,160 feet, and is in smaller quantity and much more highly mineralized than that of Denver.

The Florence wells were found while boring for oil.

Outside of these limited regions various attempts have been made to secure artesian water, as at Colorado Springs, Longmont, Love-land, and on the plains at Akron, Otis, Calhan, Kit Carson, Cheyenne Wells, Las Animas, etc., but most of them have been unsuccessful as flowing wells.

SUBDISTRICTS.

For the purpose of this investigation we may divide the portion of the State under consideration from the foothills to the one hundred and third meridian into two main districts, the Arkansas and the Platte, according to the two streams traversing it from west to east.

The Platte Valley may be subdivided into the Denver Basin, in which we will include the region from the foothills to Platteville, and the drainage area on each side; the Greeley Basin, including in it the area drained by the Big Thompson and Cache à la Poudre Rivers, to some distance on the Platte below Greeley; and the third subdistrict the Lower Platte.

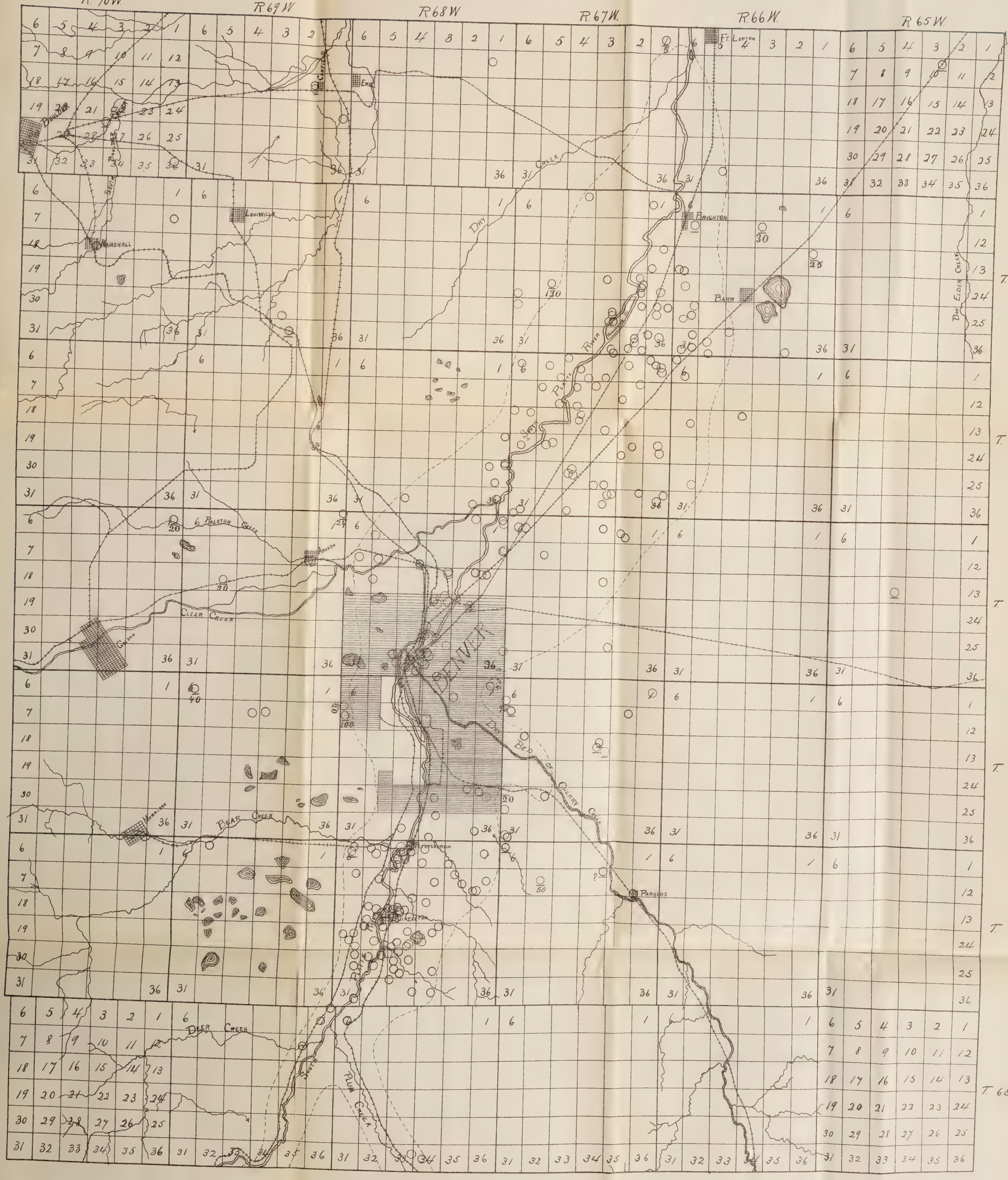
The Arkansas Valley may likewise be divided into two districts, the Florence and Pueblo Basins, extending from the foothills to a point undetermined below Pueblo, and the Lower Arkansas including the remainder of the valley. The divide between the Platte and the Arkansas is extensive enough to be considered as a separate district, as is also the divide south of the Arkansas River.

The San Luis Valley, while perhaps not properly in the area under consideration, is one which has seen such a large development of the

DENVER, COLORADO

ARTESIAN BASIN.

JULY, 1890.



artesian water supply for economic uses that a consideration of the artesian wells of the West would be incomplete without it. This basin probably includes as many wells as all of the rest of the area covered by this investigation combined.

The reasons for the limits of these districts are in most cases obvious. The Denver, Greeley, Pueblo, and San Luis Basins are regions of flowing wells, distinctly separated, and the other three regions are intended to include the area not contained in these basins.

Subdistrict.	Name.	Region included.
No. 1	Denver	Platte Valley to Platteville.
No. 2	Greeley	Big Thompson and Cache à la Poudre Valleys and the Platte from below Platteville to below Greeley.
No. 3	Lower Platte	Below the Greeley Basin.
No. 4	Pueblo and Florence	Arkansas Valley to below Pueblo.
No. 5	Lower Arkansas	Below Pueblo Basin.
No. 6	Divide	Divide between the Arkansas and the Platte.
No. 7		Divide south of the Arkansas.
No. 8	San Luis	San Luis Park.

THE DENVER BASIN.

Subdistrict No. 1 includes but little besides what may properly be called the Denver Basin. The district will include the Platte River and its tributaries from the foot-hills to Platteville, about 35 miles north of Denver.

The Denver Basin, which includes the greater portion of the above district, is one well defined by the explorations that have been made for water and by the investigations of the geologist. The accompanying map shows in outline the principal part of the basin, and the location of the individual wells where their location was known definitely enough to map.

The basin is rather an elongated oval, following the Platte as an axis, extending from near Platteville, in township 3 north, to near Castle Rock, in 8 south. In an east and west direction it extends from the foot-hills in 69 or 70 west to about 65 or 66 west, at Denver. The basin is therefore about 70 miles long and 25 miles wide.

In elevation the basin varies from 4,900 at Fort Lupton to nearly 6,000 feet at Sedalia. From Plum Creek and the Platte River, forming the axis of the basin, the land rises on either side to 100 or more feet at the distance of a mile. Immediately adjacent to the river are bottom-lands not much elevated, and then at a greater elevation usually follows a second bottom, from which the rise is to the general level of the plain above. These lines of elevation above the river indicate approximately the region of flowing wells.

Where the circle representing the well is underlined it indicates that the well is not flowing, and if figures are attached they give the distance from the surface to which the water rises. The dotted line is intended to include the area which may be called the area of flowing wells. Wells are now frequently sunk in this region without securing flowing water, and wells formerly flowing have ceased to flow. But the cause of this state of things is believed to be temporary or local, and as the physical conditions for a flow are present, the whole region is properly denominated a flowing region. It would have been better to represent the flows as they now are, but the impossibility in many cases of procuring information regarding the present condition without

a personal visit to each, which time would not permit, made it necessary to adopt a plan which would best show the information.

The most northerly flowing wells are near Brighton, on the south line of township 1 north. Their flow is small. Passing south from Brighton, the wells become frequent in the course of a few miles. In company with Professor Hay, I drove from Brighton, some 6 miles south. Nearly every farmer had a well. One near Brighton had a flow of 50 gallons per minute, while one 6 miles further south had only 15 gallons. From there on to Denver the flows increase, and some very good ones are obtained. Denver has many of them. The township in which Littleton is situated, township 5 south, has seventy. There are but few farther south. The most southerly are on West Plum Creek, south of Sedalia, which procure water at 206 feet. As we recede from the Platte and ascend the flowing wells become fewer. There are a few isolated ones near Marshall, Canfield, Erie, in the coal fields.

NUMBER OF WELLS.

The location of two hundred and thirty-five wells outside of Denver has been ascertained. Most of them are given in the accompanying tables. In Denver it has been necessary to estimate the number. In 1884 there were about eighty. It is within bounds now to estimate them to be one hundred. This would make a total of three hundred and thirty-five.

It is improbable that the list of wells outside of Denver is complete, except for some limited localities. Several wells have been reported, but with little information, and as they have not been verified in the little time at hand they are not counted.

STRATIFICATION OF WELLS.

The strata passed through has uniform characteristics, but is extremely variable both in the layers struck and in the thickness of the same layers.

The following is an example of the strata passed through, and is taken from the record of the Anderson well, and has been used before for the same purpose:

	Thickness.	Depth below surface.
	Feet.	*Feet.*
A seam of gravel and surface wash		12
Clay	17	29
Sandstone	1	30
Hard clay	94	124
Hard sandstone	8	132
Clay-slate	22	154
Sandstone (first flow)	14	168
Hard clay	24	192
Sandstone	2	194
Very tough hard clay	50	244
Sandstone (second flow)	16	260
Hard clay	30	290
Sandstone (third flow)	10	300
Blue clay	8	308
Sandstone (fourth flow)	12	320
Soft clay	15	335
Dark hard clay	15	350
Loose white sandstone (fifth and greatest flow of water)	25	375
Total depth of old well	375	375

For comparison the record of the well at the Kansas Pacific shops is given.

Artesian well at Kansas Pacific shops, East Denver.

Strata.	Thickness.	Depth below surface.
	Feet.	*Feet.*
Sand and gravel	18	18
Clay	5	23
Soft sand rock	50	73
Clay	3	76
Hard sand rock with streaks of clay	60	136
Clay	10	146
Hard sand rock with streaks of clay	134	280
Artesian strata	7	287
Hard sand rock with streaks of clay	248	535
Artesian strata	17	552
Shale	5	557
Hard sand rock with streaks of clay	41	598
Artesian strata	35.4	633.4
Hard sand rock	1	634.4

A glance at the accompanying well tables will show the extreme variability in the water strata. The number, thickness, depth, degree of porosity, all vary within short distances, so that wells close together frequently differ in all these characteristics.

A few instances will suffice to show this character of variability. The Bemis well at Littleton struck three good flows of water within 375 feet, while the well on Littleton Heights, not 500 feet away and at the same elevation, struck but one within 800 feet and that was at 458 feet.

The Burke well strikes seven flows of water within 300 feet, while the neighboring well of the Union Pacific finds but three within 600 feet and the Schindelholz well but one within 416 feet.

The following group of six wells, all in the same section, shows the characteristics of the basin:

	Flows (thickness of stratum in parentheses).					
Anderson				125 (5)	250 (1)	465 (23)
Gleason				95 (10)	300 (2)	471 (29)
Zaug				155 (10)	245 (25)	300 (25)
Montague	68 (5)	138 (30)	258 (32)	376	405	427
Sanguinette				135 (5)	185 (13)	255 (51)
Webber					185 (10)	245 (93)

None of the water strata appears in the wells above and the thickness of the same stratum when struck varies exceedingly.

Taking the difference between corresponding strata it becomes evident that the strata undulate but not with the surface of the ground. This is perhaps better shown in the table furnished by Mr. Hine, of the city engineers' office, where the depths of the strata are all expressed from a level plane. Still there is sometimes a persistence of a given stratum than considerable distances, and some of the flows are more persistent than others. Some are purely local and found in only a few wells. Through all of townships 1 and 2 south, along the Platte, a 300-foot flow is found which varies in the individual wells from 272 to 350, but is generally within 20 feet of being 300.

In Denver, two flows, those called the 375 and 600 feet flows are recognized. At Littleton there are some four distinct water strata, the different strata being indicated by the temperature of the water, which varies from 46½ to 65 degrees. The deepest is of course the warmest.

There is a similar variation in density and porosity of the sand rock in which the water is obtained whithin short distances. This is more commonly shown by the differences of flow and pressure in neighboring wells from the same stratum.

FLOWS.

In the early days of the Denver Basin nearly all wells were flowing wells, but with the continued tapping of the strata it became more common to secure only pumping wells, even in regions where flowing wells had been previously secured.

About an average flow was from 5 to 100 gallons per minute in the immediate vicinity of Denver. In the first few years of the development of the basin the wells were of small bore, as water was wanted for domestic use only. The supply was often insufficient for hotel or manufacturing purposes, and it became common to introduce pumps, which by lessening the pressure in neighboring wells caused pumps to become necessary. In consequence the bore of wells has been gradually increased, until now it is frequently 6½ inches; a few are 8 and one or two are 10 inches.

In the basin outside of Denver differences in flow are noticed according to the locality. Near Brighton, and for several miles toward Denver, the flow does not often exceed 1 or 2 gallons per minute. Some 6 or 8 miles above Brighton there are some good flows of 30 to 40 gallons per minute, but the best wells seem to have been obtained above Denver or in its vicinity.

Some of the wells are reported as remaining unchanged in flow, a few have increased, but as a general thing the report is that the flow has fallen off, sometimes entirely ceased. Many of the later wells, especially in Denver, do not strike flowing water at all. Frequently the diminution is due to the tapping of the water strata by other wells in the vicinity, thus opening other outlets, or outlets at a lower level.

The decrease in flow may be due to several causes: from other wells piercing the same stratum and lessening the pressure; from filling up with sand, stopping the flow; from insufficient casing, allowing the water to flow into upper strata instead of conducting it to the surface.

The decrease in flow from piercing the same stratum is best shown by the Charles well of Denver, because that was the first to go through the 600-foot flow. The pressure was quite constant, ranging from 68 to 71 pounds per square inch. When the Daniels and Fisher well was sunk, a few blocks away, the pressure decreased to 10 or 15 pounds, and after the McClelland well was sunk the flow was entirely lost for about a day, then reappearing with a pressure of about ten pounds. When the two latter wells were connected the pressure in the Charles well again increased. Since that time a large number of wells have pierced this stratum in Denver, and so many have resorted to pumping that the flow has entirely ceased.

Mrs. Eckhart's well, in North Denver, which had been flowing with a pressure of 35 pounds, ceased entirely when the Gurley well struck the same strata at a lower level.

The Windsor and the Barclay wells are each at the corner of Eighteenth and Laniver streets, separated by the street and a portion of their respective blocks. The Windsor well was completed August 30, 1883; the Barclay, August 4, 1884.

At different measurements this well had the following discharges:

March, 1884	gallons per minute	67½
May 6, 1884	do	40
June 6, 1884	do	32
August 4, Barclay well completed.		
August 5	do	15

A portion of the failure between June 6 to August 5 should be attributed to the seasonal variation.

The decrease in flow and the entire cessation of most of the wells in the immediate vicinity of Denver can be mostly attributed to this cause. So well is this recognized that now flowing wells are not expected in this immediate vicinity.

But outside the city of Denver there is little reason to think this cause has been influential in more than a small degree. The wells, however, have diminished in most cases, but the cause seems to be from the well having filled to some extent with sand or to defective casing, which allows the waste of the water in the upper porous layers.

In many cases cleaning has been resorted to, and the flow, or a great part of it, has been recovered.

The following are examples where this has been done:

Mrs. Cook's well, on Cherry Hill farm flowed 20 gallons per minute when sunk. It failed so that there was almost no flow. After cleaning it regained one-half its flow.

The well of R. W. Curtis had a flow of $4\frac{1}{2}$ gallons per minute in March, 1888. In January, 1890, it had decreased to $1\frac{1}{2}$ gallons. The well was found to be filled up to the flow at 350 feet. After cleaning out, the flow increased.

The Harrington well had a flow of from 8 to 14 gallons per minute for three months after completion, when it failed. It was then cleaned, and the flow was increased to from 4 to 8 gallons. This lasted for several weeks, when it failed. This well seems to have been subject to caving.

The Barclay well, which was sunk in 1884, had a flow of 40 gallons per minute, which had decreased in May, 1886, to 10 gallons. Before cleaning (May 14) measurement showed the flow to be $10\frac{1}{2}$ gallons per minute. During the operation the flow was measured several times. The progressive increase is noticeable: May 15, the flow had become—

At 4 a. m	gallons per minute..	17
At 6 a. m	do......	$21\frac{3}{4}$
At 9 a. m	do......	32

Early in July following the well was found to have again filled up 42 feet, and the flow to have decreased to 8 gallons per minute.

In the above cases it is noticeable that the full flow is not recovered. A part is due to seasonal variation; a part may be due to the reduction of pressure consequent on the increase in the number of wells.

In the country the cause most influential in bringing loss is probably poor or insufficient casing. Actuated by motives of economy the common practice is to case only through the loose material down to the stratified formations, unless the formation below caves so badly that casing is necessary. The pressure of the lower water strata is almost always greater than the upper. The consequence is that the water from below has the opportunity to enter the strata at less pressure above, or the dry sandstone, and the flow from the well is lost or lessened.

Similarly the packing at the junction of the stand-pipe and the first bed of clay is often defective. In such a case the water is allowed to fill the upper layers of the soil. The loss in water and in pressure may be great. The consequences are not confined unfortunately to the one well, but to the whole adjacent basin, and the damage may be irreparable. The fact that such careless work may be done, and the damage so great, suggests that in basins of such character it is a matter of public importance that each person putting down a well should be required by law, if necessary, to thoroughly case and pack his well.

Variation with the seasons.—The variation in the flow of wells according to the character of the seasons has become a commonly accepted fact. The upper strata show the effect sooner than the lower, and the wells near the mountain quicker feel the effect of a dry season than those of Denver.

Mr. Wadsworth, of Arvada, a good observer, says:

Our artesian wells come and go with the seasons. When the little streams in the foot-hills are pouring their contents into the loose rocks so as to dry up before reaching the valley, artesian wells in Denver and vicinity work all right; but when the streams fail in the foot-hills some of the wells cease to flow.

The most careful series of measurements of an individual well that has been obtained is that of Mr. Dwelle on the Barclay well, from 1884 to 1887, and the Windsor well in 1883 and 1884.

The Barclay well was completed August 4, 1884, to a depth of 602 feet. Two flows of water were struck and each was kept separate by casing. The measurements of Mr. Dwelle, reduced for convenience to gallons per minute, are as follows:

Measurements on the Barclay well, Denver.

Date.	Upper flow per minute.	Lower flow per minute.	Date.	Upper flow per minute.	Lower flow per minute.
	Gallons.	*Gallons.*		*Gallons.*	*Gallons.*
Aug. 4, 1884	4½	36	Apr. 8, 1886	0	12
Jan. 24, 1885	7½	51	May 14, 1886‡	0	10½
Mar. 9, 1885	(*)	(*)	May 15, 1886 (4 a. m)		17
Nov. 8, 1885	5	35½	May 15, 1886 (6 a. m)		21¾
Jan. 27, 1886	0	12	May 15, 1886 (9 a. m)		32
Feb. 6, 1886†	3	14	July 9, 1886§	0	8
Feb. 15, 1886	9	37	Jan. 17, 1887	0	7½
Feb. 19, 1886	5⅓	27			

* Both flows, 40 gallons.
† It was found the well had filled 19 feet to this date.
‡ Cleaning begun.
§ Well had again filled 42 feet.

The Windsor well, 530 feet deep, was also under the charge of Mr. Dwelle and was measured by him as follows:

Date.	Upper flow per minute.	Lower flow per minute.	Both flows.
	Gallons.	*Gallons.*	
August 30, 1883			208
November 10, 1883		127	
November 14, 1883		124	
March, 1884		67.5	
May 6, 1884	8.7	29.3	
June 6, 1884			32
August 5, after the Barclay well had been struck	1.8	13.3	

February 15, 1886, to April 6, the well was deepened. It is now pumped.

The fluctuation in the flow is noticeable, and especially the increase in February, 1886, in the Barclay well.

Mr. Dwelle, in reply to a letter, says:

I ascribe the fluctuations to two causes, viz, the cleansing of the wells by removing the sand and pulverized clay which had got into them, presumably with the water, and to the difference in the quantity of water which was being delivered to the uplifted strata which convey the artesian supply.

It will be noticed in the cases of the sudden changes of amount of flow that the least quantity flowing was in the late fall or early winter, as a rule, when there was the least amount of snow melting and the least quantity of water in the streams; while the greater flow in connection with these sudden changes was in the early spring following, when the snow was rapidly melting and the streams were full of water.

In case of the sudden change noted in February, 1886, I made a mental note at the time, as I remember, that the latter part of January of that year and the month of

February were very open, and there was a great deal of rain in addition to the melting snow at that time.

After the cleaning of 1886, the continued small supply is undoubtedly to be attributed mostly to the drain upon the supply caused by the number of new wells in the immediate vicinity.

The increase in flow reported in several cases is due to two causes, to the opening of the small channels through the water-bearing rock by the passage of the water, and to the formation of chambers of greater or less size at these places. The rapidity with which the water can pass through the sand-rock under a given pressure is limited. But if the area of the surface through which the water issues is increased, the quantity of water available is correspondingly increased. The application of this is often seen in dug wells, for it is well known that the larger the well the more water it can furnish.

Nearly all the wells seem to form a cavity or small reservoir at these strata, as evidenced by the sand brought up. In the Denver Basin this is usually in small quantity. The largest amount of sand reported being two wagon loads, or say 50 cubic feet. Ten or 15 cubic feet are more common.

The large wells flow more than the small ones, but this is principally due to the less friction and consequently the less loss of pressure the water suffers before reaching the surface.

While the water supply of the Denver Basin is as permanent as the season, it is limited, as the diminution of the flows show, and the number of wells can not be indefinitely extended. In Denver, indeed, it is probably already exceeded, though if pumping should cease most of the wells would recover their flow.

The diminution does not show that the limit of the basin has been reached, but simply that the water is taken from that vicinity faster than it can be supplied by percolation through the rocks.

Outside of Denver there is opportunity for more wells, and many are being put down.

IRRIGATION FROM WELLS.

It has been comparatively little practiced, the district being fairly well supplied with water from canals at a cost of about $15 per acre. The expense of artesian water, notwithstanding the character of the Denver Basin, which renders sinking comparatively inexpensive, is much more than this at best. But the water to be obtained from ditches is inconstant in flow and uncertain. In dry seasons, as in the present, many crops burn up for want of water.

In such a case many think of utilizing their flows which generally waste. Others who have land which can not be watered from any ditch have wells, and devoting their land to small crops, find it profitable. There are several who have artesian wells as their only source of supply. It is not possible to state accurately the number of acres thus irrigated. Nearly every well in the county furnishes water for the garden or for trees. Others irrigate from 3 to 15 acres. There are a few others, from which definite information could not be obtained, reported as irrigating more. In the aggregate, the amount is probably more than 100 acres, an amount which is not large in comparison with the whole amount irrigated in the district, but is important as showing the use which may be made of the artesian flow. It is safe to say that much more will be irrigated from this source. Ditches in Colorado are not entitled to water until all those of earlier construction are supplied. The principal ditches near Denver are of recent date, and consequently

in dry seasons such as the last few years have been, great loss of crops ensue. In this locality, especially, the demand for water at any price is great, and the use will increase to a moderate extent.

REPLIES TO INQUIRIES.

The following are some of the replies that have reached me in response to circulars and other efforts. Mr. Max Grossman says:

I have done no well-digging during the past two years. During 1883, 1884, and 1885 I put down a number of wells in Denver and vicinity. Did not keep records, but furnished the Denver city engineer with records from memory and full particulars regarding the amount of flow, etc.

In 1885 I put down an artesian well in Greeley, Col., and in 1887 one at Raton, N. Mex. The balance of the well-drilling I have done in the West was for oil, in townships 19 and 20 south, range 69 west, constituting the Florence, Tremont County, oil district, in Colorado. In one of the wells I put down there I struck a flow of water, all the others, one of them 3,021½ feet deep, were, as far as water is concerned, absolutely dry, except those in the river bottom, which had water for the first hundred feet, but no flow that rose to the surface.

Other parties have obtained artesian wells near Florence, notably one well on Four Mile or Oil Creek, 4 miles from Canyon City, owned by the Canyon City Oil Company, and one each on the J. A. McCandless and Orange White Ranches, about 2½ miles east of Florence, sunk and owned by the Florence Oil and Refining Company. The formation in the oil district is shale. The deep well above mentioned did not reach the bottom of the shale. The only sand found was 10 feet of dark rock at about 2,680 feet. Oil is found in this district in seams or crevices of the shale at varying depths.

Some years ago while stopping with a farmer named, I think, Stevens, about 7 miles southwest of Sedalia, on the Denver and Rio Grande Railroad, on West Plum Creek, he informed me that on the very top of a table mountain near his place there was a clear spring of running water that never went dry. This mountain is about 700 feet higher than the surrounding country, and at least 6 miles from the foot hills of the range, standing alone.

Peter Maynes, of Littleton:

In my opinion the artesian streak for this section of Colorado has its origin from basin south of Croggy Peak, about forty-five miles from here and east of south branch of South Platte River. There are three large streams running into this basin, and only one small stream running out.

Thomas Withers, of Denver:

Upon artesian flow, however, I am sure in my own mind that the flow which we get here outcrops east of the divide between the Platte and Republican Rivers and forms the Republican River. Other plains' streams may get more or less of it, but the South Fork, Arickaree, and North Fork of the Republican are formed solely from this flow. The sedimentary rocks, or rocks of the secondary and tertiary formations, being tilted up towards the west, the water from the mountains leaches down into the porous sandstones and is carried under the Platte and its basins' eastern rim to where these strata outcrop, and forms these streams of soft clear water which vary for neither season nor weather. Of course they carry off the surplus storm waters, but they go quickly. Hence, artesian water may be struck all the way from the mountains to the outcrop of the water-bearing strata, but at some places the surface elevation may be too great, or the pressure too little for a surface flow.

A. P. Switzer, of Denver:

I have drilled sixty-five wells in Colorado, mostly all in Denver. The record of Rosedale well is about a copy of the Denver wells, excepting extreme variations in water supply. I have drilled wells that flowed 400 gallons per minute in Denver. The same well flows 100 now, owing to the great number of wells in close proximity.

Bear Creek, where it comes out of the mountains at Morrison, Colo., loses 500 cubic inches of water in passing over the lower sandstones; Platte River I think possibly more; Clear Ceek not quite so much. We have never reached the lower sandstones in Denver.

In my opinion the overflow of this artesian basin appear as the numerous springs on the head of the Republican River; all soft water springs. If we could put a drill down to the lower sandstones, in my opinion we could get an enormous supply of soft water with great pressure from Denver to Nebraska line.

The San Luis Valley is the greatest known artesian water basin of Colorado. Water there is obtained in great abundance for irrigation; one well of 1,000 feet will irrigate 400 acres. Pueblo also has wells at 1,400 feet, but the water carries so much iron and salt that it will kill plants. I am now drilling near the Spanish Peaks, but at a present depth of 1,100 feet the water carries 210 grains to the gallon of solids, mostly salts.

If a well were to be put down, say 3,000 feet, in Eastern Arapahoe County, it would, I think, open up wonderful water courses. The State compels us to supply it with a record of all wells. You will find a number of mine in the Secretary of State's office.

John B. Myers, Littleton:

I engaged in the artesian-well business in what is known as the "Denver artesian basin," five years ago. Our method of boring wells is known as the "pipe-tools" method, the pipe varying from 1 to 3 inches in size, depending upon the size of bore and depth to be reached.

The first two years of the history of artesian wells the bore was about 3 inches, because of the fact that flowing wells were invariably struck, until wells were bored in such numbers that the pressure was lessened and they ceased to flow. During that period wells were only used for domestic purposes, but when the second period arrived, it became necessary to introduce pumps, because of the increased use for water for factories, hotels, and other purposes. The usual bore of wells in this period was 4½ inches, which size has been gradually increased to 6⅝, and some are being bored as large as 8 inches.

About an average flow with wells first bored was from 5 to 100 gallons per minute. Some of these wells have but slightly diminished to the present time, while others have ceased to flow entirely; principal cause due to the number of wells in close proximity, while some have ceased flowing because of insufficient casing.

The evidence on hand would warrant the belief that the artesian water is permanent, but limited. Frequently, in a given area, we find a well with a large flow, say 50 gallons per minute, with less than 1 pound pressure at the surface, while a well within 300 yards will only flow 2 gallons per minute with a pressure of 25 pounds per square inch. We believe that the character of the material passed through, more than the size of bore or altitude, affects such flow.

The character of material passed through varies greatly within 200 feet. A well sunk on First street, Denver, near Cherry Creek, known as the "Edward Kittle Well," we passed through 52 feet of gravel, finding "blue clay," which we here denominate as "bed-rock," 30 feet. This was followed by 700 feet of sand, rock, grey, shale, cutting water strata at 350, 465, and 650 feet; last flow only coming to the surface. Then 200 feet of shale, being a total depth of 982 feet.

A well sunk to 1,000 feet south of the above, on Sherman avenue, to a depth of 850 feet, we found bed-rock at a depth of 32 feet, after passing through gravel that distance, bed-rock being the blue clay, passing through the latter to a depth of 405 feet, followed by sand-rock to a depth of 6 feet, in which we cut a water stratum, the same flowing to surface without pressure. This was followed by 445 feet of blue clay, without encountering either rock or water.

Usually we find a similarity as to the depth of water strata, as well as a similarity as to formation.

We find the water strata undulating as the surface, but not with it. We find four distinct water strata, the temperature of the water clearly indicating the stratum. The temperature varies from 46½° to 65° Fahr.

The method of sinking wells is as follows: Small bores of from 300 to 500 feet deep are usually sunk with the "spring-pole outfit" necessitating the labor of from three to six men, one man turning drill, the other to depress the pole, number of men varying with depth. Larger bores are sunk with engines of ten to twelve horse-power, necessitating two men to the shift, work usually being continued through the 24 hours. Engineers being paid $2 to $2.25 per day, with board. Drillmen are paid $2.25 to $3 per day with board. We reckon 1 foot of boring per hour, of whole time consumed in setting up and completing well of 4½ inches in diameter, or 6 inches per hour for 5⅝ inches diameter of casing.

Contracts vary as to price and location. I take contracts for 3½-inch casing to first flow (which in Denver is usually 350 feet), to any depth not exceeding 1,000 feet, cased with 2½-inch casing from such 350 feet to bottom of bore, the same being perforated where flows are cut, I furnishing stand-pipe, all necessary casing, at $1.50 per foot. Have in some instances set up and completed such wells, 850 feet in depth, in ten days of twenty-four hours. Ordinarily three weeks. A 5⅝ well, contract price $2.75 per foot. A 5⅝ well, as usually sunk, is 5⅝ inches to a depth of 350 feet; 4½ from 350 to 450 feet; 3½ from 450 to bottom of bore, usually 650 feet; 6⅝ well, done in same manner, $4.25 per foot, contractor furnishing everything.

In the Denver Basin the water strata are not feasible for purposes of irrigation, from the fact that cost of well overbalances any possible profit. The topographical

as well as the geological formation of the artesian basin is such that the available supply of water, in proportion to the land to be irrigated, would bear about the same relation that a 2-inch hose would to the extinguishing of the Chicago conflagration.

The water bed of the San Luis Valley would yield a sufficient quantity of water to irrigate every square foot of its cultivatable land.

In one case a man sunk six wells 200 feet apart, the wells being 3 inches in diameter, 400 feet in depth, each well yielding 50,000 gallons of water per day. All six wells being sunk so near each other, and not affecting each other, is to me satisfactory proof of the sufficiency of the strata.

Seventeen wells sunk in La Jara, to a depth of 125 feet to 185 feet, in a radius not to exceed 300 feet, bore 1¼ inches, yield each 15 gallons per minute, temperature 46½°. Cost of each, $50. Method used in boring, hydraulic jetting. Four men completing each well in two days. Saw one well being sunk 40 feet in one hour. Total cost of tools and machinery, high estimate, $75. Two wells at Alamosa, 850 feet each, 6-inch casing, yield 100 inches of water, or nearly 3 cubic feet per second, temperature of water 65°.

I have bored 63 wells in this basin, of which, as the law requires of us, you will find succint reports at the office of the secretary of state.

S. F. Couch, Littleton:

I am about 2¼ miles west of Mr. Chatfield, in the northwest quarter of section 3, township 6, range 69 west, and supposed to be out of the artesian basin. Having no well of my own, I have not filled out that particular form. In my position as water commissioner I go over a very considerable portion of Arapahoe and Douglas Counties and also a small part of Jefferson County. In Douglas I do not find many artesian wells, but in Arapahoe there are a great number.

B. F. Wadsworth, Arvada:

The two wells that have been put down here are 22 feet to bed-rock. Then alternate layers of fire clay, mud streaks, blue clay, shale, coal, and sand to the depth of about 180 feet to first water rock, then 120 feet hard rock and second water. Then on to 420 feet through water rock to third flow at 460 feet. Water raised to 60 feet of surface. Good supply. Not thoroughly tested as to volume, but very good in quality. In regard to springs they are increasing every year. My ditch, 4 miles long, used to go dry as soon as the water was turned off at the head. Now, after twenty-eight years' use, it runs 15 inches of water from the springs along its way. Other ditches are similar. Ralston Creek, a thunder-shower stream in 1860, runs 50 inches of spring water in the dryest winters. These springs are a great blessing to our people, and should be guarded from the water-sharks who are now moving to divert them by under-draining to sell again to the farmers.

Immense springs can be made by diverting small streams near timber line to the north slope of the mountains, thus keeping up a constant flow in a dry season. [Our artesian wells come and go with the seasons. When the little streams in the foot-hills are pouring their contents into the loose rocks so as to dry up before reaching the valley, artesian wells in Denver and vicinity work all right; but when the streams fail in the foot-hills, some of the wells cease to flow.]

B. F. Wadsworth, Arvada:

The Stanley well in section 17, Township 3, range 69 west, was put down about six years ago, with about the same result as the Arvada well, and Reno Park well, as far as a flow of water is concerned, but being on a high ridge it is quite hard to pump from. They had much trouble with caving of the well while trying to get deeper than 600 feet.

As to the Artesian wells coming and going with the seasons, referred to in a former letter, I got my first intimation of it from Denver people, and it was so interesting to me that I watched the wells and made inquiries until I came to the conclusion that late in the fall of a very dry season the poorer wells would show signs of weakening, and in one case the Ashland school well, was drilled out anew, and a pump put in before the winter's snow in the mountains gave the new impetus.

Nearly all the small streams in the mountains sink before reaching the hogbacks, thus filling the strata of porous water rock for one hundred of flowing and pumping wells. Wells near the mountains would naturally feel "pulse beat" more than those situated far from the mountains, and where the grade of water strata is less.

The investigation in which you are engaged is a grand one and should be encouraged by all.

Chas. W. Dwelle, C. E., Denver:

I ascribe the reasons for changes of flow of Windsor and Barclay artesian wells to two causes, viz, the cleansing of the wells by removing the sand and pulverized clay which had got into them, presumably with the water, and to the difference in

the quantity of water which was being delivered to the uplifted strata which convey the artesian supply. These strata outcrop next to or in the bases of the foot-hills on the west or on the divide between the Platte and Arkansas on the south, and possibly also on the divide between Cherry Creek and Coal or Sand Creek on the east of the Artesian basin which supplies the wells.

It will be noticed in the cases of the sudden changes of amount of flow, that the least quantity flowing was in the late fall or early winter, as a rule when there was the least amount of snow melting and the least quantity of water in the streams; while the greater flow in connection with these sudden changes was in the early spring following, when the snow was rapidly melting and the streams full of water.

In the case of the sudden change noted in February, 1886, I made a note at the time, as I remember, that the latter part of January of that year and the month of February were very open, and there was a great deal of rain in addition to the melting snow at that time.

I think reference to the weather reports will verify me in this, and I ascribed, as I have said, the change in flowing condition of the wells to the quantity of water delivered to the artesian strata by the humid early spring and late winter over and above what was received by them in the previous fall, which was a comparatively dry season, to the best of my recollection.

It should be remembered in this connection that the Denver artesian basin is a small one comparatively, with a disproportionately great number of wells, many of them improperly cased and allowing the water to leak away probably through underground crevices and cavities, while at that date especially there were quite a number of wells, mainly on the ranches on the lower elevations, or rather depressions of the basin, which were allowed to run to waste. Indeed I think there is no question but what quite a number of wells not protected with casing at all have been sunk in this basin, mainly on the ranches.

If now it is considered what a drain upon the supply all these wells would make in a dry season, it is not surprising that the flow should increase very materially during a succeeding wet one.

As regards the resistance to flow of water offered by the sand and clay filling the wells for 20 or 30 feet in depth, the nature of the clay should be taken into consideration, and it should be remembered that it is the same material which forms the walls of the water strata, having a decided tendency to pack, and when so packed in combination with the sand, offering great resistance to the passage of the water through. As one of the stratum walls, it is in fact, in its compacted and dense condition, as we know must be the case, entirely impervious to water.

It should also be remembered that at the time the wells were cleaned and the flow had been diminished by reason of the clay and sand, it had also been very materially diminished by the cause already suggested, as well as the more sufficient reason that more wells had been sunk upon the basin than it could fully supply without a decreased flow.

Table of data on artesian well construction, Denver, Colo.

[From H. Himber, chief sewer inspector, Denver, Colo.]

Owner.	Depth from surface.	Depth below city planum.	Average cost per linear foot.	Total cost.	Depth of flow below city planum.			Location.	Case, inches.	Flow.	Remarks.	
					First.	Second.	Third.				January 1, 1884.	December, 1889.
Spitzer	330	309	\$1.50	\$500.00	106	184	276	11th and Larimer	....	10 gallons through 1-inch pipe, forty-four seconds.	Mr. Spitzer says well flows 84 gallons per minute.	Flow light; runs irregular; takes forty minutes to run 40 gallons; supply, ten 4-room houses.
Do	270	267	1.54	415.00	....	.....	.....	15th and Platte, N. D.	4	10 gallons through $\frac{1}{2}$-inch pipe, fifty-three seconds.	....	Water rises 4 feet above ground; runs $2\frac{1}{2}$ gallons in one and one-half minutes.
Lion Brewery	290	281	1.74	510.00	227	247	.....	8th and Larimer	4	390 gallons through 2-inch hose in fourteen minutes.	....	Runs to top of ground; use pump; average, 20,000 gallons per diem.
J. K. Mullin	$322\frac{1}{2}$	313	2.77	800.00	115	151	298	8th and Wazee	6	....	....	No pressure; use water for boiler and drinking purposes only.
Phil Zang	300	259	3.31	1,000.00	146	165	250	7th and Water	4	....	....	Sunk 220 feet more; use the 300 flow in summer for ice; use the 520 flow now; pressure, 25 pounds; use 100,000 gallons per diem.
Denver Brewery	360	329	2.23	800.00	101	169	309	9th and Lawrence	4	10 gallons through $\frac{3}{8}$-inch pipe, ninety seconds.	Owner claims 100,000 gallons per diem.	Two wells, 360 and 700 feet deep; use about 75,000 gallons per diem; have to use pump.
Anheuser-Busch	314	302	2.13	675.00	118	178	228	10th and Wazee	3	10 gallons through $\frac{1}{2}$-inch pipe, ninety seconds.	Well in good condition.	Sunk 294 feet more; use in summer, for ice machine, 5,000 gallons daily.
Mellsheimer	354	336	......	....	....	....	....	10th and Larimer	2	....	....	Use pump, but have some pressure; pump 32,000 gallons daily.
Grant Smelter	620	....	4.03	2,500.00	...	....	...	Grant Smelter	$5\frac{5}{8}$	Two flows—upper 35 pounds pressure, lower 45 pounds; 10 gallons through $\frac{1}{2}$-inch pipe, eighty seconds.	....	Pressure and flow light; very little flowing. "Will put in pump."
City Laundry	406	370	2.38	927.00	....	.....	.....	27th and Lawrence	4	10 gallons through $\frac{1}{2}$-inch pipe, eighty seconds.	Claims 35 pounds pressure.	Sunk 128 feet deeper; pump use, 3,000 gallons per diem.

W. C. Lothrop	425	389	2.82	1,200.00	149	279	380	18th and Lawrence	3	10 gallons, ½-inch pipe, one minute.	....	Flow ceased; will put in pump.
Bennett	500	459	5.00	2,500.00	....	....	....	31st and California	4½	10 gallons, ⅜-inch pipe, one minute forty seconds.	Bennett claims 18 pounds pressure.	Use pump (windmill); supply eight houses and run two wagons; pump 2,600 gallons daily.
Glassman	278	256	.90	250.00	....	....	....	18th and Central, N. D.	....	10 gallons, ½-inch pipe, one and one-half minutes.	Six ½-inch streams flowing at same time does not diminish pressure.	Use hand pump; flow about ceased.
Gurley Bros	525	438	2.85	1,500.00	123	213	423	Block 3, river front	4	10 gallons, ½-inch pipe, fifty seconds.	40 pounds pressure; a very fine well.	Sunk 175 feet deeper; no pressure; no flow; put in pump.
Bandenhauer's	365	292	2.85	1,500.00	201	233	274	18th and Fairview	4	....do....	Magnetic pressure strong as ever.	Flow ceased; use pump; domestic purpose only.
Poole's	278	252	.90	250.00	....	....	....	18th and Central	2½	10 gallons, ½-inch pipe, two minutes.		
Windsor Well	530	499	2.83	1,500.00	301	489	500	18th and Larimer	5⅝	96,000 gallons per day; has been 300,000 gallons.	....	Use pump; supply Windsor Hotel, Barclay Block, etc.; 200,000 gallons daily.
Menca & Alley	290	251	....	....	....	....	....	10th and Platte	2	10 gallons, ½-inch pipe, two minutes.	....	Will not run to second story; runs 2½ gallons in forty-five seconds.
Saddle Tree Factory.	300	278	....	....	....	....	....	14th and Platte	2	10 gallons, ½-inch pipe, three minutes.	Claims 17 pounds pressure.	Flow irregular; houses connected with Holly.
Anderson, T. G	375	335	2.67	1,000.00	114	204	250	11th and Colfax	3	....	....	Do.
Swift	460	414	1.96	900.00	234	302	402	28th and Champa	3½	10 gallons, ½-inch pipe, one minute.	Supplies thirty-four families.	Flow ceased.
Electric Light Company.	340	326	....	....	....	....	....	23d and Wazee	4½	....	....	Do.
Schmdelholz	416	393	2.16	900.00	....	....	....	26th and Holladay	3	10 gallons, ½-inch pipe, two minutes.	....	Do.
Collins, Henry	385	354	2.73	1,050.00	....	....	....	12th and Stout	5½	....	....	Do.
Taber Opera	....	....	....	....	....	....	....	....	....	....	....	Pump use; about 26,000 gallons per diem.

Artesian wells of the Denver Basin.

No.	Name.	Location.	Diameter of bore.	Date sunk.	Total depth.	Flows, depth from surface.	Pressure per square inch.	Flow per minute.	Increase or decrease.	Work done in irrigation.	Other work.	Authority and remarks.
			In.				*Lbs.*	*Gals.*				
1	Winbourn	T. 1 W., R. 67 W., Sec. 1.			904	475, 700						Owner. Water comes to 4 feet of surface.
2	P. W. Snyder	T. 1 S., R. 67 W., Sec. 4.	3	1886	406	200, 400	7	30				State engineer's record.
3	F. Aichelman	13	2½	1886	350	206	2	$\frac{1}{5}$	Diminished some.		Dairy; domestic.	Owner. State engineer's record.
4	Mrs. Black	13	3	1887	315	200, 206, 315	1	1	Unchanged		Domestic	Do.
5	G. C. Braenlin	20		1889	730	400						Owner. Water 130 feet of surface.
6	Theo. Lohf	NE. 22		1887	215			2			Domestic	Owner. State engineer's record. Temperature, 58°.
7	....do	Center 22		1888	340							Owner. State engineer's record.
8	W. S. Lee	23	2½	1885	218	125, 140, 190	9	6	Decreased to 2 gallons.		Stock, fish	Do.
9	G. C. Griffin	SE. 23		1885	340	240, 300		3	Unchanged		Domestic	Owner. State engineer's record. Temperature, 58°.
10	A. Hagus	24			250	180	8	4				———. State engineer's record. Temperature, 52°.
11	F. Reithmann	NW. 25	3	1887	306	265	4	1	Decreased 2 gallons.			Owner. State engineer's record.
12	J. S. McCool	27	3	1885	155	150, 155	13	20	Unchanged		Domestic	Owner. State engineer's record. Temperature, 52°.
13	T. A. McCool	27		1888	304		13	20	... do		....do	Owner. State engineer's record.
14	A. R. McCool	SW. 27	2½	1886	134	136	3	3	... do		....do	Do.
15	Mrs. S. Brantner	34	3		272	150, 225, 272, 287.		12½	....do			State engineer's record, 1888.
16	D. E. Young	35	2	1885	316			6	Decreased to 5 gallons.			Do.
17	R. W. Curtis	35		1890	600	350, 420, 450		5	Decreased			Owner. Flow recovered by cleaning.
18	Mrs. M. Brantner	36	3	1887	430		19	15	Decreased one-third.	Lawn; trees.	Stock	Owner.
19	Davis & Day	36	3½	1890	640			Small	Diminished slightly.		....do	Do.

20	J. F. Wolpert	T. 2 S., R. 67 W., Sec. 3.	3	1886	323	300		8	Decreased from 10 gallons.			State engineer's record, 1883.
21	F. M. Morris	4		1888	300			5				Do.
22	Mrs. R. Morris	NW. 4			300	210		40	Decreased from 45 gallons.			Do.
23	H. A. Vanevery	SE. 4	3		300	300	10	8				Do.
24	M. Cline	5	3	1886	280	239	16	10	Decreased to 5 gallons in 1888.			Do.
25	S. Cline	SE. 5	3	1886	416			16				Do.
26	R. A. Southworth	6		1885	480	340		4	Ceased entirely.			Owner.
27	G. W. Sigler	NW. 8	3		300	85, 300	20	50				State engineer's record, 1888.
28	A. H. Hanscome	SE. 8	4	1889	328	98, 207, 310	25	60	Unchanged	10 acres	Domestic; stock.	Owner.
29	C. N. Campbell	16	3	1888	440	150, 390–422		60				State engineer's record.
30	G. A. Starbird	16		1887	600	180, 350, 580	13	40	Unchanged	12 acres	Domestic	Owner.
31	J. I. Brewer	NE. 18	3	1886	322	150, 315		20				State engineer's record, 1888.
32	George Wooley	SE. 18		1886	316	316		35	Decreased to 30 gallons.			Do.
33	D. Wolpert	19			600	340, 580	20	128	Decreased to 60 gallons.			Do.
34	Platte Land Co	23	3½	1890	856	335, 580, 840		10				Owner.
35	J. S. Vanderlip	N. 29	3	1885	300	83, 135, 286		8	Decreased to 5 gallons.	Garden	Domestic; stock.	State engineer's record, owner.
36	Mrs. C. H. Cook	31	3	1887	531	280, 490	25	20	Decreased to 10 gallons.	2 acres	Domestic	Owner. State engineer's record.
37	....do	S. 31		1887	302	141, 239		60	Decreased to 30 gallons.		Domestic; dairy.	Do.
38	Platte Land Co	SW. 33	3½	1890	828½	448, 564, 810	10	12			Domestic	Owner.
39	F. C. Fowler	34	3	1887	356	145, 165, 195, 215, 252.		3	Unchanged			State engineer's record.
40	J. C. Knowles	NE. 35		1887	416	150, 300, 416	6	100	Decreased to 90 gallons.			Do.
41	C. C. Towle	T. 3 S., R. 67 W., S. 3		1885	617	220, 460, 550	6	50				Do.
42	D. P. Broadwell	5	4½	1887	810							Owner. Water 5 feet of surface.
43	....do	5		1887	750		20	7	Ceased from caving.			Owner.
44	C. C. Towle	6			617		13	40	Decreased from 75 gallons.			State engineer's record.

Artesian wells of the Denver Basin—Continued.

No.	Name.	Location.	Diameter of bore.	Date sunk.	Total depth.	Flows, depth from surface.	Pressure per square inch.	Flow per minute.	Increase or decrease.	Work done in irrigation.	Other work.	Authority and remarks.
			In.				*Lbs.*	*Gals.*				
45	P. E. Gleason	8	....	1886	620	482	28	40	Decreased to 10 gallons.	8 acres	Domestic and stock.	Owner.
46	Platte Land Co	15	3½	1888	858	782–792, 825–833.	15	25	....	....	....	Do.
47	....do	SE. 27	3½	1889	881	604, 787, 840–868.	....	15	....	....	....	Do.
48	....do	T. 40, R. 67 W., S. 1	3½	1890	915	715, 799½	....	....	....	....	....	Do.
49	L. Dugal	SW. 6	....	1888	770	350, 500, 770	....	....	....	....	....	George Comstock.
50	M. A. Smith	NW. 7	....	1888	715	528–530, 700–715.	....	....	....	....	Domestic	M. A. Smith.
51	Bush & Mone	15	....	1888	1103		....	....				
52	South Capitol Hill	18	....	....	670	....	....	....	....	....	Stock	Owner.
53	McMurray	30	....	....	850	....	....	....	....	....	Domestic	Do.
54	Larkspur	T. 9 S., 67 W	....	1889	560	Below 500 feet.	....	....	....	....	....	George Comstock.
												George Comstock. Water to 116 feet of surface.
55	Dr. Stedman	T. 2 S., R. 68 W., NE. Sec 24.	....	1885	325	....	7	6	Diminished to 3 gallons.	....	Domestic and stock.	Owner.
56	A. L. Ish	25	....	1886	337	327, 333	20	60	Diminished from 100 to 60 gallons.	....	....	State engineer's record, 1888. Temperature, 58°.
57	J. B. Ish	NE. 25	....	1887	400	....	....	30	Diminished from 50 to 30 gallons in 1888.	....	....	State engineer's record, 1888.
58	W. W. Groves	NW. 25	....	....	389½	200, 389	10	40	Diminished to 30 gallons in 1888.	....	....	Do.
59	M. M. Phelps	NE. 25	....	1886	445	445	14	50	....	....	....	State engineer's record, 1888, Temperature, 62°.
60	John Cline	S. ½ 25	2	1886	407	135, 245, 376	20	30	....	....	....	State engineer's record, 1888.
61	B. F. Harrington	W. ½ 33	....	1886	821	260, 440, 465	....	8	Diminished from 14 gallons.	....	....	State engineer's record, 1888. Owner.

62	F. P. Watson	35	3	1886	420	135, 175, 375	16	30	Diminished from 35 gallons.			State engineer's record, 1888
63	I. W. Epler	Center 36		1887	408	80, 200, 408	14	20				Do.
64	E. Reithman	T. 3 S., R. 68 W., Sec. 1.	4	1884	318	214, 318		35	Diminished to 15 gallons.			Do.
65	T. D. Storm	2		1886	470	185, 385	40	166				Do.
66	J. Cook, jr	NW. 2	5⅝	1888	1069½	640, 723						Do.
67	W. S. Hamill	SW. 2	2	1888	658	290, 395, 400, 606.	40	120				Do.
68	Public school	SW. 5	1¼	1887	385	375	15	25	Diminished to 10 gallons.			Do.
69	A. S. Lane	SW. 7	1½		400	360	4½	20	Diminished to 15 gallons.			Do.
70	John Wolff	8	2¼	1885	410		25	125	Diminished to 40 gallons.		Domestic	State engineer's record. Owner.
71	Sand Creek House	12	5	1887	586	303, 586		10		Trees	do	State engineer's record. Owner, 1890.
72	J. H. Moser	9	3	1888	494	140, 210, 393, 460.	20	60	Increased		do	State engineer's record, 1888.
73	Mrs. C. A. Loomis	NW. 13		1888	532	106, 184, 210, 272, 368, 417.	40	200			do	State engineer's record.
74	Mrs. E. M. Loomis	14	3	1888	504	100, 164, 187, 200, 244, 265, 300. 504.		75			do	Do.
75	W. H. Clark	SW. 15	2	1887	381	95, 165, 185, 220, 260, 375.	7	12			do	Do.
76	M. D. Clifford	SW. 15	2⅓	1887	175	65, 140	4	9			do	State engineer's record.
77	Globe Smelter	NE. 15	7⅞	1886	505	300, 465, 500.	50	100	Diminished from 173 gallons.		Domestic; boilers.	Owner.
78	A. Anderson	22	2⅓	1888	488	125, 250, 465.	15	30				State engineer's record.
79	Mrs. Gleason	NE. 22	2½	1888	506	95, 300, 474	12	25				Do.
80	Ph. Zang	NE. 22		1888	330	155, 245, 305	5	20				Do.
81	D. A. Montague	NW. 22	2	1887	444	65, 138, 258, 380, 405, 427.	40	50	Diminished from 90 gallons.		Domestic	Owner. State engineer's record.
82	L. Sanguinette	NW. 22	2½	1886	296	135, 185, 255	8	15				State engineer's record.
83	J. H. Webber	NW. 22	2⅓	1888	338	185, 245	5	9				Do.
84	Smith Bros	Sec. 23	1½	1885	360			5 to 10	Diminished about one-third		Domestic; boilers.	Owners.
85	Grant Smelter	23	5⅜		621	130, 180, 240, 325, 575.	1	Small	Diminished			H. Himber. Colorado Scientific Society.
86	Bennett	SW. 26	4½	1883 or '84	500		18				Supply eight houses and run two wagons.	H. Himber. Pumps 2,600 gallons daily.

Artesian wells of the Denver Basin—Continued.

No.	Name.	Location.	Diameter of bore.	Date sunk.	Total depth.	Flows, depth from surface.	Pressure per square inch.	Flow per minute.	Increase or decrease.	Work done in irrigation.	Other work.	Authority and remarks.
			In.				*Lbs.*	*Gals.*				
87	B. & M. R. R.	NW. 27	9		600	225, 350, 500					Railroad purposes.	Max Grossmayer. Pumping.
88	Swift	SE. 27	$3\frac{1}{2}$	1883 or '84	457	277, 345, 447		15	Flow ceased			H. Himber.
89	Neighborhood	E. 27	3	1883 or '84	460	392, 440	32					Colorado Scientific Society, 1884.
90	Schindelholz	SE. 27	3	1883 or '84	416	One flow	15					Do.
91	City Laundry	SW. 27	4	1883 or '84	406		35 (1884)	13 or 15	Diminished			H. Himber.
92	U. P. R. R.	SW. 27	$5\frac{5}{8}$	1889	634	280, 535, 598					Boilers, by pumping.	W. Ashton, civil engineer. Water to 7 feet of surface
93	Electric Ill'tg Co	SW. 27		1889	629	No flow					do	Owners.
94	C. Burke	SW. 27	$2\frac{1}{2}$	1888	328	75, 165, 190, 240, 250, 265, 275.	6	10				State engineer's record.
95	John Breheny	SE. 28			346	120, 214, 267		15				Do.
96	Glassmann	SW. 28		1883	278			10	Flow nearly ceased.			H. Himber.
97	Bandenhauer	SW. 28	4	1883	365	274, 307, 348			Flow ceased			H. Himber. Now pumped.
98	Poole	SW. 28	$2\frac{1}{2}$	1883	278							H. Himber.
99	Spitzer	SW. 28	4	1883	270		2	2	Diminished			Do.
100	Beaver Bro[illegible]ks	NW. 32		1888	502			100				State engineer's record.
101	Gurley	NE. 32	4	1883	525	210, 300, 510	40 (1884)	204	Ceased			H. Himber. Sunk to 700.
102	Evans	NE. 33	$5\frac{5}{8}$	1888	376	200, 350						State engineer's record.
103	American Hotel	NE. 33	$5\frac{5}{8}$	1884	545		15		Diminished to 0.		Hotel purposes.	C. H. Smith. Now pump.
104	D. L. & G. R. R.	N. 33	$5\frac{5}{8}$	1890	624	262, 316, 355, 575.					Railroad boilers.	W. Ashton, civil engineer. Water 20 feet of surface.
105	Metropolitan	NE. 33	8	1883 or '84	545	365, 545					Hotel purposes.	Colorrdo Scientific Society. Pressure 85 pounds in 1884.
106	Ph. Zang	NW. 33	4	1883	600	187, 206, 291	18	300	Diminished to 0.		Brewery	Owner. H. Himber. State Engineer; Colorado Scientific Society. Use 100,000 gallons daily.
107	Menca	NW. 33	2		290		7	$3\frac{1}{2}$				H. Himber. December, 1889.
108	Saddle Tree	NW. 33	2	1883	300		17 (1884)					H. Himber. December, 1889. Flow irregular.

109	Anheuser	Center 33	4	1883–'87	604			16	Diminished to one-tenth.		Brewery	Owner. H. Himber.
110	G. C. Moore	SE. 33		1884	609				Diminished		Laundry	Owner.
111	Lion Brewery	SE. 33	4	1883	294	236, 246	9	20	Diminished to almost 0.			Himber. Colorado Scientific Society.
112	Denver Brewery	SE. 33	4	1883	360	150, 200, 306, 358.	20		Diminished			Himber. Colorado Scientific Society. Now pump.
113	Mellsheimer	SE. 33	2		354							Himber. Still some pressure. Pump 32,000 gallons daily.
114	Anderson	SE. 33	3	1883	375	154, 244, 290, 308, 350.	25		Diminished			Himber. Colorado Scientific Society.
115	H. Collins	SE. 33	5½		385				Ceased			H. Himber.
116	Spitzer	SW. 33		1883	330	327, 205, 297		84 (1884)	Diminished to 1 gallon.			Do.
117	Mullin	SW. 33	6		322½	122, 158, 305					Boilers	Do.
118	Barclay	NW. Sec. 34	5⅝	1884	602				Diminished		Pump 120,000 gallons daily.	Owners.
119	Windsor	NW. Sec. 34	5⅜	1883	997½	174, 332, 520, 531, 635, 735, 750.		200	Diminished to 65 gallons, 1884.		Pump 200,000 gallons daily.	Do.
120	W. C. Lothrop	NW. Sec. 34	3	1883 or '84	425	185, 315, 416		15	Ceased			H. Himber.
121	Tabor Opera	NW. Sec. 34		1883 or '84	390	179, 220, 333, 375.	36		Diminished from poor care.		Pumped	Colorado Scientific Society.
122	Charles	NW. Sec. 34		1883	580	235, 364, 564	70		Pressure diminished to 20 gallons, 1884.		Boilers	Colorado Scientific Society, Mr. Charles. Now pumped.
123	Daniels & Fisher	SW. Sec. 34	6⅝	1884	662	450, 605	25		Diminished		Boilers; domestic.	Owners.
124	McClelland	SW. Sec. 34	5⅜	1884–'85	607		25	120	Diminished			Do.
125	Eckhart	SW. Sec. 34	4		580				Decreased			Colorado Scientific Society.
126	Kinsey	SW. Sec. 34	4		625	280, 580, 615	25	60	Probably diminished.			Do.
127	State of Colorado	36	3½	1888	802½	500, 525, 600–602.						State engineer's record.
128	Loveland	T. 4 S., 68 W. N. Sec. 1		1888	355	200, 340				Lawn; trees	Domestic	Owner.
129	South Capitol Hill	SW. Sec. 2		1888	671							State engineer's record.
130	Tramway Co	N. Sec. 3	6⅝	1888	647½	290, 460, 570						Do.
131	Baker's Villa	NW. Sec. 4		1888	636	310, 600		65	Diminished to nearly 0.			Owner.
132	Villa Park	NW. Sec. 7		1889	500	200. 400, 500						
133	J. L. Killie	7		1888	360	305						State engineer's record. Never flows.
134	Univ. Park	25		1886	740	640		⅛	Diminished to 0 in 3 months.			J. C. Shattuck. Filled with sand.
135	A. C. Fisk	26		1887	700			Small	Diminished			Owner.

Artesian wells of the Denver Basin—Continued.

No.	Name.	Location.	Diameter of bore.	Date sunk.	Total depth.	Flows, depth from surface.	Pressure per square inch.	Flow per minute.	Increase or decrease.	Work done in irrigation.	Other work.	Authority and remarks.
			In.				*Lbs.*	*Gals.*				
136	Rosedale	27	3½	1886	627	300, 450, 580		11	Diminished to 6 gallons.	Trees; lawn	Supplies 20 families.	A. P. Switzer.
137	J. Bell	33		1890	620	470, 565	Good	10			Domestic	George Comstock.
138	J. Jones	34		1887	125			8 or 10				
139	J. O. Lawton	34	3½	1888	565	410, 563		20	Unchanged	Hot house	Domestic	Owner.
140	C. A. Olin	Sec. 1	3	1887	450	140–160, 360–370.	60	180	....do			State engineer's record.
141	Charles Moore	SW. 3			675	450, 650	15	20			Domestic; stock.	J. B. Mayers.
142	Mrs. B. Magnes	4			580	350, 580		20	Decreased	Lawn; trees.	Stock	George Comstock.
143	C. E. Wyman	4			600		15	20				J. B. Mayers.
144	Puff	4			550							Do.
145	Ferris	4			350			20				Do.
146	A. Candler	4	3½	1889	720	346, 558, 570, 579, 620.	15	10	Increased 2 gallons per minute.		Domestic	Owner.
147	J. Playter	5	3½		550	216, 550		10	Decreased to 0			George Comstock.
148	Isaac McBroom	5			150			15				Captain Campbell.
149	John McBroom	5			172			30				Do.
150	Military Park	5			500			30				J. B. Mayers.
151	Fort Logan	6	6⅝	1888	685	460, 476, 485, 492, 665.		10			Domestic	Captain Campbell, State engineer.
152	J. C. Hopkins	8	3	1888	864	56, 794, 802						J. G. Hopkins. Pumped.
153	Eureka Farm	11		1886	710	350, 450, 640	40	60	Decreased one-third.		Domestic	A. V. Culter.
154	Bonita	SW. 12	3	1889	725	440, 695	12–16	80	Unchanged	15 acres	....do	D. M. Richards, George Comstock.
155	Olehow	15			542			25				J. B. Mayers.
156	W. G. Sprague	NE. 16			550	525–550		6	Decreased			George Comstock.
157	Stark Nursery	16		1888	709			10	Unchanged	Orchard and nurseries.		Owners.
158	....do	16		1889	733			10	....do			Do.
159	F. Bemis	16	3½	1887	375	175, 310–315, 350–370	20	15	....do	3 acres garden.	Domestic	F. Bemis. State engineer's record.

160	Littleton Heights	16	3½	1890	810	458		1			Wastes	J. B. Mayers.
161	F. W. Shuckhart	16	4	1889	601	200		15	Not decreased		Domestic	F. W. Shuckhart.
162	J. B. Mayers	16			510		6	25			Town supply	J. B. Mayers.
163	....do	16			375	175, 250, 350		35	Decreased to 25.			Do.
164	....do	16			265	240	7	15				Do.
165	....do	16			520	72, 510.						Do.
166	W. G. Sprague	16			258			10				Do.
167	School House	16 or 17			520	243, 350, 475					Domestic	Do.
168	C. Olmstead	16 or 17			500			15			....do	Do.
169	H. H. Shepard	16 or 17			510			10			....do	Do.
170	Hotel	17			510						....do	Do.
171	Knight & Cray	17	2½	1888	300	185, 240–243, 288–291.	10	7	Unchanged			State engineer's record.
172	Boyd Skelton	17			360	200					Domestic	J. B. Mayers.
173	R. I. Spotswood	19		1888	287			25	Increased 5 gallons per minute.	1 acre, garden.	Stock	R. I. Spotswood.
174	C. E. Hill	19	3½	1889	467	254, 281, 314, 333, 393.		20	Unchanged		Domestic	Captain Campbell. State engineer's record.
175	D. M. Hunter	NW. 19	3½	1888	500	258, 304, 390, 445, 470.		16	Decreased one-half.	1 acre	....do	D. M. Hunter. State engineer's record.
176	Patterson	20						25				J. B. Mayers.
177	D. Lenhart	20			480	Near bottom		15	Unchanged		Domestic; stock.	George Comstock.
178	Orchard Grove	NW. 20	2	1884	525	112, 378		9	....do		Domestic; fish.	State engineer's record.
179	C. R. Gallup	21			536		5	10	Probably decreased.			J. B. Mayers.
180	G. H. Elliott	SW. 21	2½	1888	580	About 500		8		Trees, fruit	Domestic	George Comstock.
181	J. B. Mayers	SE. 21			635		5	10				J. B. Mayers.
182	G. J. Burnett	NE. 22									Domestic.	
183	W. W. Chapman	NW. 22		1884	440	425–440		20	Decreased	Lawn; trees	Stock	George Comstock.
184	G. J. Burnett	NE. 28	2½	1888	540	About 520	15 or 20	50	Unchanged	8 acres	Domestic	Do.
185	John Curtis	NW. 20		1889	635	Below 600		8	Decreased	Garden	Domestic; stock.	Do.
186	H. H. Curtis, jr	NW. 28		1889	328	315–328		20	Increased	Over 2 acres; garden; orchard.	Domestic	Do.
187	Levick	NW. 28				213, 350, 450, 520.	10	10				J. B. Mayers.
188	H. H. Curtis, jr	SW. 28		1884	340	322–340		16	Decreased to 5 gallons.	Trees; lawn	Domestic	George Comstock.
189	Levi Palmer	29		1883	301	267, 285–301	14	10	Decreased	....do	....do	Do.
190	Peter Magnes	30			365	200		36			....do	J. B. Mayers.
191	....do	30		1889	250			12			For picnics	George Comstock.
192	J. M. Fox	T. 6 S., R. 68 W., Sec. 6.			596	218		2	Increased to 4 gals.			J. B. Mayers, George Comstock.
193	L. L. Kemp	33		1884	443	80, 400, 440	30	15	Unchanged	2 acres	Domestic; stock.	L. L. Kemp, George Comstock.

Artesian wells of the Denver Basin—Continued.

No.	Name.	Location.	Diameter of bore.	Date sunk.	Total depth	Flows, depth from surface.	Pressure per square inch.	Flow per minute.	Increase or decrease.	Work done in irrigation.	Other work.	*Authority and remarks.
			In.				*Lbs.*	*Gals.*				
194	G. Manhart	T. 7, R. 68 W., Sedalia, Sec. 14.	4	....	710	3[illegible]0, 500, 650, 700.	....	....	....	Garden, etc	Pumped	George Comstock.
195	A., T. & S. F. R. R.	T. 7, R. 68 W., Sedalia, Sec. 14.	5	1889	650	350, 500, 600	....	....	....	....	....	Do.
196	Jones	About Sec. 36	....	1887	1440	218	10	12	Unchanged	....	....	A. P. Switzer. Most southerly flowing well.
197	O. L. Bright	T. 3 S., R. 69 W., Sec. 1.	$2\frac{1}{2}$	1888	908	412	....	....	....	....	....	A. L. Davis, Arvada.
198	Reno Park	11	$6\frac{5}{8}$	1890	724	240, 285	....	....	....	....	Domestic	B. F. Wadsworth.
199	E. L. Chatfield	T. 6 S., R. 69 W., Sec. 1.	....	1888	365	....	....	10	Increased from 7 gallons.	....	....do	E. L. Chatfield.
200	Wm. Shellabarger	11	....	....	600	250	....	Small	....	....	....	J. B. Mayers.
201	H. W. Allen	T. 1 S., R. 70 W., Sec. 12.	2	1889	400	196	....	3	Unchanged	....	Domestic	H. W. Allen.
202	Scranton	16, 3 S., 65 W	3	1887	800	....	....	....	....	None	....	R. D. Hobart.
203	Mrs. D. A. Stewart	NE. 32, 1 N., 66 W.	....	1888	500	325	....	1	....	....	....	State engineer's record.
204	A. E. Meek	13, 1 S., 66 W	....	1888	800	Less than 170 feet.	....	....	....	....	....	A. E. Meek. Water to 25 feet of surface.
205	W. Craig	30, 1 S., 66 W	....	1887	300	190	10 to 12	5	Decreased	Reservoir	Stock	A. E. Meek.
206	J. M. Mumford	31, 1 S., 66 W	$2\frac{1}{2}$	1888	446	430	....	$\frac{1}{2}$	Unchanged	Few trees	Domestic	J. M. Mumford.

NOTES AND ADDITIONAL INFORMATION.

No. 1. Most northerly well of the Denver Basin.
No. 2. Fifteen feet above the Platte River.
No. 3. Temperature of water 56°; cost $250.
No. 4. Cost $200.
No. 6. Sunk by owner. Strata as follows:

Clay to	105
Soft sandstone	118
Blue clay	126
Sand	127
Soft bluestone	127½
Soft sandstone	134
Soft bluestone	139
Soft stone	142
Clay	145
Sandstone	151
Blue clay	152
Soft bluestone	186
Sand	186⅓
Blue clay	215

No. 7. Water comes near the surface.
No. 8. Cost $185. First flow has temperature of 53°.
No. 9. Cost $300. Temperature 58°.
No. 11. One flow only. Cased 97 feet.
No. 12. Cost $200.
No. 13. Cost $200.
No. 14. Cased for 30 feet.
No. 15. Second flow had temperature of 56°; cased 40 feet.
No. 16. From second flow.
No. 17. Drilled 390 feet, 1888; flowed 4½ gallons per minute. Decreased to 1½ gallons in January, 1890, when sunk deeper. Found filled with sand. On cleaning flow increased.
No. 18. Cost $260. Strata as follows:

Strata.	Thickness. Ft.	Thickness. In.	Depth. Ft.	Depth. In.
Surface				
Bed-rock (clay)	16	10	16	10
Sandstone	8		24	10
Black clay	22		46	10
Black slate	2	2	49	
Artesian sand	200		249	
Slate and coal	3		252	
Artesian sand	22		274	
Blue slate	5		279	
Artesian sand	100		379	
Slate	30		409	
	21		430	

No. 19. Cost $700.
No. 20. Cased 60 feet.
No. 22. Water from 90 feet rises, but does not reach the surface.
No. 23. Cased 25 feet.
No. 24. Cased 36 feet. Strata as follows:

Strata.	Thickness. Feet.	Depth. Feet.	Remarks.
Surface and blue clay to		82	
Sandstone and iron pyrites	9	91	Water, but does not reach surface.
Blue clay	20	111	
Sandstone	19	130	Water to 80 feet from surface.
Soft clay	23	153	
Hard sandstone	19	172	Water to 70 feet from surface.
Blue clay	18	190	
Sandstone	19	209	Water to 15 feet from surface.
Gray clay	30	239	
Water-rock	21	260	Flow raised 36 feet.
Gray clay	21	281	

No. 25. Flow given is that of June 4, 1888.
No. 27. Cased 25 feet.
No. 28. Cost $171.15. After being shut off, fine gray sand, mixed with clay, is brought up, 4 quarts at a time; cased 35 feet; water strata, 98–100, 207–210, 310–318.
No. 29. Cased 49 feet.

Strata.	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Surface	54	54	
Blue clay	96	150	
Sand-rock	6	156	
Water-rock	12	168	First flow 15 gallons per minute.
Blue clay	30	198	
Blue sand-rock	32	230	
Blue clay	100	330	
Shale	60	390	
Sand-rock	32	422	Second flow 60 gallons per minute.
Water-rock	18	440	

No. 30. Cost $800; reservoir built to hold sixty days' run; began to irrigate from it in 1889.
No. 31. Cased 34 feet.
No. 34. Cased with 3½-inch casing to 564 feet; then 2½-inch to 764. There are 207 feet of 2½, giving a lap of 7 feet; 70 feet of this pipe is perforated, to allow the flow from the second level to enter the 3½-inch casing. The strata are as follows:

	Feet.		Feet.
Surface	50	Clay	525
Blue clay to	207	Sand-rock	535
Sand and water rock	335	Clay	560
Blue clay	338	Hard sand-rock	580
Sand rock	376	Water-rock (water, 3 gallons per minute)	645
Blue clay	387	Shale and clay	764
Sand-rock	420	Hard sand-rock	765
Blue clay	432	Sand-rock	806
Hard sand-rock	433	Water-rock	840
Blue clay	470	Clay (water, 10 gallons per minute)	856
Sand-rock	508		
Shale	510		

No. 35. Cased 30 feet. Flow reported 8 gallons per minute when completed; 5 gallons in May, 1888; 7½ gallons by measurement May, 1890.
No. 36. Cost $1,000; cased 485 feet. Flow 20 gallons per minute first two years. Failed to nearly nothing; had it cleaned; regained half flow. Water was struck at 180; no flow.
No. 37. Cost $700. Temperature from 141 feet, 50°; from 239, 55°. Strata as follows:

Surface to	feet	36	Soapstone	feet	203
Soapstone to	do	36	Sandstone	do	207
Iron pyrites	inches	8	Soapstone	do	237
Soapstone	feet	139	Cap-stone	do	239
Sandstone	do	141	Water-rock (flow 52 gallons)	do	299
Water-rock (water, 10 gals.)	do	145	Soapstone	do	301

No. 38. Cased with 3½-inch casing to 563 feet; with 2½-inch to 826 feet.

Strata.	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Surface	125	......	
Blue clay	62	187	
Sand-rock	20	207	
Blue clay	32	239	
Sand-rock	6	245	
Shale and clay	203	448	
Sand-rock	5	453	Water to 100 feet of surface.
Blue clay	12	465	
Sand-rock	103	568	Water from 564, 2 gallons per minute.
Blue clay	48	616	
Sand-rock	27	643	
Blue clay	87	730	
Sand-rock	40	770	
Blue clay	38	808	
Sand-rock	17	825	Water, 810, 12 gallons. Raised 20 feet above surface.
Blue clay	3½	828½	

No. 39. Cased 47 feet.

No. 41. First flow, 8 gallons.

No. 42. Cased 98 feet.

No. 43. Cased 410 feet. Commenced to case October, 1889. It then began to bring up white sand and shale.

No. 44. The flow of 40 gallons per minute was in May, 1888.

No. 45. At first raised 60 feet high; now 12 feet. Has two reservoirs; would water about 2 acres without them. There are two flows, the last between 530 and 620.

No. 46. Cased the full depth with $3\frac{1}{2}$ and $2\frac{1}{2}$ inch casing. Strata are as follows:

	Feet.
Surface, quicksand, clay	155
Green shale	164
Coal	165
Shale and clay	178
Blue sand-rock	181
White sand-rock	193
Shale and clay	198
Sand-rock	228
Shale	231
Clay	255
Sand-rock	256
Clay	476
Water-rock (water to 4 feet of surface)	484
Clay	490
Shale	512
Hard sand rock	516
Clay and sand-rock	562
Shale	582
Sand-rock	590
Clay, sand-rock, and shale	750
Sand-rock	782
Water-rock (water 10 gallons per minute)	792
Sand-rock	803
Coal	804
Sand-rock	807
Clay	825
Water-rock (water 15 gallons per minute)	833
Shale	858

No. 47. Cased with $3\frac{1}{2}$-inch casing to 537, then with $2\frac{1}{2}$-inch to 825, with a perforated piece at the 787-foot flow, to allow water to enter. The well is connected between the $4\frac{1}{2}$-inch stand-pipe and the $3\frac{1}{2}$-inch casing so as not to leak.

The strata are as follows:

	Feet.
Surface	36
Yellow clay	70
Blue clay	177
Sand-rock	196
Blue clay	285
Sand-rock	311
Blue clay	334
Sand-rock	355
Blue clay	371
Very hard sand-rock	375
Blue clay	377
Hard sand-rock	379
Blue clay	430
Water rock (water to 120 feet of surface)	434
Clay and sand-rock	496
Tough clay	537
Hard sand-rock	540
Blue clay	583
Water-rock (water to 80 feet of surface)	590
Very hard sand-rock	$591\frac{1}{2}$
Shale (water from 604 to 40 feet of surface)	604
Water-rock (at 787 flow 3 gallons per minute)	789
Tough clay	825
Sand-rock	840
Water-rock (flow 15 gallons per minute)	868
Blue clay	881

No. 48. Cased to 567 feet with $3\frac{1}{2}$-inch casing; to 790 with $2\frac{1}{2}$-inch casing

This well seems to be located at the confluence of Tollgate and Sand Creeks. The strata dip in a northeast direction. The water strata are pinched, and at no place exced 2 feet in thickness.

The strata are:

	Feet.
Clay to	9
Rotten sandstone	69
Soap-stone	89
Fire clay	104
Sandstone	116
Clay	181
Sand-rock	196
Clay	276
Hard rock	279
Blue shale	299
Clay	334
Sand-rock	343
Shale	403
Clay	443
Sandstone	451
Clay	463
Sandstone	478
Shale	508
Hard rock	513
Shale	567
Sand-rock	572
Shale	707
Sand-rock	713
Water strata (water)	715
Shale	790
Rock	798
Water strata (water to 60 feet of surface)	$799\frac{1}{2}$

	Feet.		Feet.
Clay	819½	Clay	865
Sand-rock	821	Shale	880
Shale	826	Clay	888
Mineral	827	Sand-rock	891
Clay	837	Clay	896
Shale	857	Shale	915
Sand-rock	859		

No. 49. Cost $1,000. No flow. Water comes to 70 feet of surface.
No. 50. Cost about $2,500 for well and casing. Pump, boiler, stand-pipe, etc., extra.
No. 51. Cost $3,500.
No. 52. Cost $1,890.75.
No. 53. Water comes to 20 feet of surface.
No. 54. Most southerly well. Elevation 6,670 feet. Nearly all depth was sand-rock. Some crops are raised here without irrigation.
No. 56. Cost $275. Brought up black sand in small quantities.
No. 57. Temperature 58°.
No. 60. Cased 57 feet. Temperature 62°.
No. 62. Cost between $1,500 and $1,600, exclusive of pump, windmill, etc. The well was completed about 600 feet deep November, 1886. Flow was from 8 to 14 gallons per minute for several months, when it failed. After cleaning it regained a flow of from 4 to 8 gallons, and continued for two or three weeks and failed. Then it was sunk to 821 feet but obtained no more water. It brought up some fine sand at first.
No. 63. Casing of 3 inches for 50 feet, of 2 inches for 150 feet.
No. 64. The flows were small from 80 feet; 10 gallons per minute from 200 feet; 20 gallons from 408.
No. 65. Cased 214 feet with 4-inch casing.
No. 66. The strata passed through are as follows:

	Feet.		Feet.
Sand, soil, and gravel	15	Water-rock, principally with intervening strata of fire-clay (first flow)	285
Soap-stone and rock	85	Fire clay, some sand-stone	385
Hard-rock	97	Water vein (second flow)	470
Sand-rock	182		
Hard-rock	185		

No. 67. Cased 723 feet; from 640 feet water rose to 100 feet of surface; from 723 to 51 feet.
No. 68. Cased 400 feet, 2-inch casing; number of section is doubtful; record is as follows:

	Feet.		Feet.
Gravel and soil	20	Fire-clay	300
Soap-stone	60	Sand-rock (second flow 6 gallons)	395
Fire-clay	212	Fire-clay and soap-stone	400
Sand-rock	13	Sand-rock (third flow)	586
Fire-clay	225	Sand shale (flow from 606 feet 120 gallons)	636
Sand-rock (first flow 1 gallon)	290		

No. 69. Cased 265 feet with 1¼-inch casing; the pressure was 15 pounds; in 1888 had become reduced to 2 pounds per square inch.
No. 70. Cased 275 feet with 1½-inch casing; pressure reduced from 4½ to 3 pounds per square inch.
No. 71. This well was sunk by hand with spring-pole in eighteen days, at a cost of $300; cased 335 feet; some soap-stone and white sand have been brought up. Flow was 3 barrels per minute; is now 1.
The record is:

	Feet.		Feet.
Surface soil to	19	Hard rock	175½
Soap-stone	135	Water-bearing rock (flow 3 gallons)	181½
Hard rock	135½	Hard rock	182
Water-bearing rock (flow 1 gallon)	141½	Soap-stone	335
Hard rock	142	Water-bearing (flow 125 gallons)	410
Soap-stone	175		

No. 72. Cased for 49 feet.

No. 73. Completed July 24. Pressure then 20 pounds per square inch; flow 60 gallons per minute. September 12, same year, Mr. Montague reports the pressure to have increased to 30 pounds per square inch; the flow to have doubled.

The record is:

	Feet.
Surface	20
Soap-stone	47
Clay	50
Soap-stone	75
Water sand-rock (water rose to 14 feet of surface)	100
Sand-rock	140
Water vein (flow, 4 gallons per minute)	145
Fire-clay	150 / 210
Water vein (flow, 6 gallons per minute)	245
Soap-stone and clay	390
Flint rock	393
Water vein (flow, 20 gallons)	435
Fire-clay	460
Water vein (flow, 60 gallons)	494

No. 74. Between Central Park and Riverside Cemetery. The record is as follows:

	Feet.
Surface	18
Soap-stone	94
Sand-rock	106
Water sand-rock (first flow)	116
Fire-clay	125
Flint rock	126
Fire-clay and soap-stone	184
Flint	185
Water-rock, sand (second flow)	195
Fire-clay	210
Sand-rock	245
Flint (two crevices, 6 inches each)	253
Water vein	253½
Flint	255
Water	260½
Magnetic iron	261½
Water	262
Hard crystal rock	264
Water vein	264½
Flint	266½
Water vein	267
Fire-clay	272
Water-bearing sand-rock (flow)	300
Fire-clay	303
Hard sand-rock	305
Water vein	313
Fire-clay	321
Water vein	326
Crystal rock	329
Fire-clay	360
Crystal rock	362
Fire-clay	382
Sand-rock	385
Fire-clay	400
Flint	402
Sand shale	415
Flint	417
Sand-rock	425
Fire-clay	451
Iron and white flint (flow ?)	452
Clay	457
Water vein	460
Clay	470
Water vein	490
Fire-clay	502
Blue shale	507

No. 75. Cased with 30 feet of 4-inch casing, and with 42 feet of 3-inch. The strata are as follows:

	Feet.
Surface	30
Soft soapstone	40
Hard rock	49
Soapstone	100
Sand-rock (water 1 gallon per minute)	105
Fire-clay	115
Sand-rock	130
Fire-clay	164
Sand-rock (water 2 gallons per minute)	177
Fire-clay	187
Sand-rock (water 8 gallons per minute)	200
Fire-clay	220
Sand-rock (water 10 gallons per minute)	244
Flint-rock	245
Sand-rock	265
Fire-clay	282
Sand-rock	300
Sand-shale, sand-rock, fire-clay, blue shale, and hard rock strata	455
Sand-rock (water)	470
Tough sand-rock	488
Water-rock (water 75 gallons per minute)	504

No. 76. Cased with 3 and 2 inch casing to 65 feet. The strata are:

	Feet.
Surface	34
Soapstone	95
Water-rock (flow 1 gallon per minute)	100
Soapstone and clay	160
Hard rock	165
Water vein (flow 2 gallons)	175
Fire-clay	185
Water vein (third flow 3 gallons)	195
Sand-shale	220
Water (fourth flow 5 gallons)	230
Sand-shale and clay	266
Water vein (fifth flow 10 gallons)	300
Sand-shale and clay	375
Water vein (sixth flow 12 gallons)	381

No. 77. D. A. Montague, the contractor, says: "Found flowing water at a less depth than ever found in any well in this State that I know of." The record of strata is:

	Feet.
Surface	20
Soapstone	65
Water (1 gallon per minute)	70
Fire-clay	80
Sand-rock	85
Soapstone	100
Fire-clay	138
Hard rock	140
Water vein (9 gallons per minute)	175

No. 78. Cost about $3,000. Contract price $2 per foot. This included drilling and putting casing in place. At first it brought up some sand. Each flow is separately cased: 7¼, 5⅝, 4⅝ inch casing, respectively. Stand pipe through the surface material is 10 inches in diameter. The flow has decreased from 173 to 100 gallons per minute, probably from sand.

No. 79. Cased 34 feet with 2½-inch casing. The strata passed through were as follows:

	Feet.
Surface	31
Soapstone and fire-clay	125
Water-vein (3 gallons per minute)	130
Fire-clay and soapstone	250
Flint-rock	251
Sand-rock (9 gallons per minute)	276
Fire-clay, soapstone, and occasional thin strata of sand-rock	465
Water-vein (30 gallons per minute)	488

No. 80. Cased 35 feet with 2½-inch pipe. Flows at 95 to 100 feet, 3 gallons per minute; 302 to 337, 9 gallons; from 477 to 506, 25 gallons per minute.

No. 81. Soapstone and fire-clay to 155 feet; water-vein (3 gallons per minute) 165 feet; fire-clay and soapstone, 245 feet; water-vein, 5 gallons per minute, 270 feet; fire-clay, etc., 305 feet; water-vein, 20 gallons per minute, 330 feet.

No. 82. Cost $700. When first completed two wagon loads of sand was brought up. It then flowed 90 gallons per minute, now 50 gallons. Flows of water from 65 to 70 feet, 1 gallon per minute; 130 to 168 feet, 5 gallons per minute; 258 to 290 feet, 26 gallons per minute. Other flows were found at 376 feet, 30 gallons per minute; 400 feet, 75 gallons per minute, and heaviest flow below iron rock (probably pyrites), 6 inches in thickness, struck at 427 feet. The well has 3-inch casing to 37 feet, and 2-inch to 57 feet.

No. 83. Cased for 32 feet with 2½-inch casing.

No. 84. Cased for 120 feet with 2½ and 2 inch casing. The formations passed through are: Surface to 29 feet; soapstone and fire-clay, 185 feet; water-vein, flow 3 gallons per minute, 195 feet; fire-clay and soapstone, 245 feet; water-vein, flow 9 gallons per minute, 338 feet.

No. 85. There are about ten other artesian wells within half a mile from us, and all seem to be flowing. We think having so many so near together has affected the flow of all to some extent.

No. 86. In 1884 387 feet were cased with 7⅝-inch pipe; 558 feet with 5⅝. Main flow from 575 feet. The outer casing is perforated in two places to admit upper flows.

No. 88. Now pumping; 400,000 gallons daily reported.

No. 89. Cased to 345 feet. Pressure, at first, 32 pounds; in 1884 the Colorado Scientific Society reports 8 pounds.

No. 92. Since sunk to 534 feet. Now pumped.

No. 93. Total cost, $1,280. Contract price, $1.50 per foot. The water comes to 7 feet of the surface. Several other wells in the vicinity are pumping from the same water strata, which is probably the reason the well does not flow.

The following is the record of the strata passed through:

Strata.	Thickness.	Depth below surface.	Strata.	Thickness.	Depth below surface.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand	10	....	Sand-rock	10	328
Clay	1	11	Clay	15	343
Sand	7	18	Sand-rock	10	353
Clay	7	25	Hard sand-rock and iron pyrites	2	355
Sand	11. 6	36. 6	Artesian strata	3	358
Sand-rock	6. 60	43. 2	Clay	12	370
Clay	92	135	Sand-rock	8	378
Sand-rock	20	155	Shale	2	380
Clay	55	210	Sand-rock	7	387
Sand-rock	10	220	Clay	40	427
Clay	40	260	Sand-rock	24	451
Sand	2	262	Clay	23	474
Artesian strata	8	270	Shale	20	494
Clay	8	278	Clay	35	529
Sand-rock	8	286	Sand-rock	46	575
Clay	5	301	Artesian strata	40	615
Sand-rock	9	310	Sand-rock	8. 10	623
Clay	6	316			
Artesian strata	2	318			

No. 95. The well is at 330 Gerspach avenue. Cased 265 feet with 2½ and 1¼ inch casing. The strata are—

	Feet.		Feet.
Surface to	30	Water-vein (flow — gallons)	195
Soapstone	75	Fire-clay	234
Water-vein (flow 1 gallon per minute)	80	Flint	235
Soapstone	100	Water-vein (flow 3 gallons)	240
Sand-rock	105	Fire-clay	250
Fire-clay	125	Water-rock (flow 6 gallons)	264
Sand-rock	130	Flint	265
Fire-clay	165	Water-vein (flow 10 gallons)	273
Water-vein (flow 2 gallons)	175	Flint	275
Fire-clay	190	Water-vein (flow — gallons)	338

No. 96. On Argo street, Denver. Cased 241 feet with 2½ and 1¼ inch pipe. The strata are—

	Feet.		Feet.
Surface to	31	Flint	272
Soapstone	111	Fire-clay	279
Sand-rock	116	Water-vein (flow at 275 feet, 15 gallons)	309
Soapstone (flow from 120 feet, 1 gallon)	151	Fire-clay	317
Fire-clay and sand-stone (flow from 214 feet, 3 gallons	245	Water-vein	329
Flint	246	Hard rock	330
Fire-clay	255	Sand-shale	346
Water-vein (flow at 267 feet, 5 gallons)	271		

Nos. 97, 98, 99, 100. (See Himber's table.)

No. 101. Contractor says "ought to have been cased, but parties would not."

No. 102. Since sunk to 700 feet. At first only to 525 feet, with casing the entire distance. The pressure was 45 pounds per square inch.

No. 103. In the rear of the railroad building, corner of Fifteenth and Larimer streets. Cased for 320 feet with 5⅝-inch casing.

No. 104. On lot 21, block 20, East Denver. Cost, $1,611. Two separate casings, 400 feet of 5⅝-inch; 545 feet of 4¼-inch. Water is now 10 feet below surface; the head used to be 35 feet. A pump has just been put in. A little sand has been brought up at the shops.

No. 105. Contract price for boring, $1.50 per foot. Total cost, $1,225. Water rises to 20 feet of surface. Another well from the same water stratum, only about 300 feet away, is being constantly pumped.

No. 106. Corner of Sixteenth and Holladay streets. Cased 360 feet with 8-inch pipe.

No. 107. The first well sunk after the discovery of artesian water; cost $1,500.

No. 110. Lot 1, block 37, West Denver; cost $755. Was sunk to 314 feet in 1883 with 4-inch casing, furnishing an immense amount of water rising in pipes to the third story, where it emptied into a large receiving-tank. Owing to a great number of wells being sunk all around us the flow commenced decreasing until it was barely

sufficient to supply the boilers. In 1887 the well was deepened to 600 feet casing the lower part with 3-inch casing. Now get ample supply by pumping. Have no means to measure the natural flow.

No. 111. Block 101 East Denver; cost $950. Fifth flow is used.

No. 113. Now pump. Have a second well 700 feet deep. (See Himber's table.)

Nos. 119, 120. Corner Larimer and 18th street. See variations given in text.

No. 122. The assistant engineer in charge May, 1890, said the well was no longer used. Has been pumped for some years.

No. 123. Corner of 15th and Curtis. The first well to reach the 600 feet flow.

No. 124. Corner of 16th and Lawrence; cost $1,650. When first finished water rose 60 feet above surface, now only 30 feet below. At 350 feet water bearing sand struck, but without pressure enough to bring to surface. Case is $6\frac{5}{8}$-inch pipe. Now pumped. Pump is 100 feet below surface.

No. 125. An attempt was made to sink the well deeper in 1890, but the tools becoming caught the well was abandoned.

No. 128. At the northeast corner of the City Park of Denver.

No. 129. Cost $800 for windmill and all. Pumped.

No. 130. The strata are:

	Feet.		Feet.
Sand to	40	Sand	266
Iron cap	41	Unstratified shale	511
Yellow sand	81	Sand	526
Shale	181	Shale	582
Sand	201	Water-vein (water comes to 121 feet of the surface)	605
Sandstone and slate	251		

No. 131. Cased for 595 feet, $6\frac{5}{8}$-inch reducing to $4\frac{3}{4}$ and $3\frac{1}{2}$; water at $255\frac{1}{2}$ to $305\frac{1}{2}$, at 460 to 510, at 570 to 620.

No. 132. Water used in manufacture of ice. Use 100,000 gallons daily. Some sand was brought up at first.

No. 135. Filled 100 feet with sand.

No. 136. A suburban well. Cost $1,265.

No. 137. Cost $1,250. Cased to bottom. The strata are:

	Feet.		Feet.
Surface material	60	White sand (flow 2 gallons per minute)	480
Soapstone	300	Black shale (soft, caved badly)	580
White sand (flow 3 gallons per minute)	320	White sand (flow 6 gallons)	620
Blue shale	450	Black shale	627

No. 140. Cased to 548 feet. From 410 feet, temperature is 58°; from 563, 66°. The strata are:

	Feet.		Feet.
Sand and bowlders	62	Water (3 gallons per minute, 58°)	410
Blue sand-rock	130	Sand	450
Clay and shale	240	Clay and sand-rock	548
Water-rock (no flow)	245	Water (20 gallons per minute, 66°)	563
Shale and clay	400	Clay	565

No. 141. Cased with 3-inch and 2-inch casing for 345 feet.

	Feet.		Feet.
Surface	34	Water vein (flow 3 gallons per minute)	170
Soapstone	60	Soapstone, shale, and fire-clay	370
Hard sand-rock	80	Water-bearing (except 13 feet of clay about 400 feet; flow 180 gallons)	450
Soapstone	160		

No. 147. At Petersburg. Cost $1,080. The flow has increased 2 gallons per minute. Cased with $3\frac{1}{2}$-inch casing to 276 feet, with $2\frac{1}{4}$-inch to 620. The casing is perforated at each of the water strata. The record of strata is:

	Feet.		Feet.
Surface	40	Blue clay	558
Brown shale	50	Water-rock	568
Blue sand-rock	70	Brown shale	570
Blue clay	90	Water-rock	575
Blue sand-rock	135	Blue clay	579
Blue clay	260	Water-rock	584
Water-rock (water did not rise to surface)	270	Blue clay	590
Clay and sand-rock (flow)	346	Sand-rock	602
Water-rock	356	Blue clay	620
Blue clay	395	Water-rock	625
Sand-rock	410	Black shale	720

The flow increased from 346 feet downward.

No. 152. Total cost, $2,467.77; 42,000 gallons pumped daily. The record of the strata is as follows:

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	7.	7	Water strata	0.6	493
Mixed clay and gravel	20	27	Sandstone	4	497
Soft sandstone	8.	35	Water, clay, and shale	30.6	527.6
Brown sandstone	72	107	Shale	6.6	534
Soapstone	100	207	Sandstone with sand and clay	46	580
Shale	82	289	Sandstone	8.6	588.6
Hard sandstone	12	301	Shale	1.6	590
White sand (first water-bearing stratum)	5	306	Shale	11	501
Hard sandstone (rises to 63 feet of surface)	2	308	Sandstone	2	603
Shale	82	390	Hard sandstone	22	625
Water sand (but no water)	5	395	Mineral sand	1.3	626.3
Shale	53	448	Shale	1.9	628
Soft sandstone	5	453	Sand	6	634
Hard sandstone	76	460.5	Shale and sand alternately	24	658
Water strata	6	466.6	Hard sand-rock	7	665
Hard sandstone	10	476.6	White water-sand	4	669
Water strata	4	480.6	Sandstone	2	671
Hard sandstone	5	485.6	Shale	6	677
Water strata	2	487.6	Sandstone	2	679
Hard sandstone	5	492.6	Hard sand	6	679.6
			Shale	4.6	684

Captain Campbell also gives the following wells, located within 3 miles of the Government reservation, which are not included in the tables. Most of them are not mapped and not counted.

List of artesian wells near or within 3 miles of reservation.

	Depth.	Number of flow.	Gallons per minute.
	Feet.		
Charles Treat	300	First	1
Peter Magnes	500	Second	12
Denver Transfer Company	300	First	7
Adam Rucker	615	Third	15
Judge Rucker	475	Second	30
Joseph Brown	540	Third	20
J. Jones	627	...do	35
John Morrison	767	First	12
Judge Steck	735	....do	12
O. Stehn	425	. do	1
Mr. Harwood	500	Second	25
Mr. Hates	510		10

No. 153. Cost $2,250. At 804 feet water was struck which came to 45 feet of the surface. The record is:

	Feet		Feet.
Surface	56	Sandstone	265
Sandstone	63	Blue clay and shale	794
Blue clay	236	Sandstone	802
Sandstone	241	Shale	804
Shale	251	Sandstone and water	

No. 154. Put down for several neighbors at the corner common to their farms. Now owned by Messrs. Culter, Horn, and Canning. Cost $1,440. "The well flows with greater force after 6 p. m."

No. 155. Cost $725.50. Cased 800 feet.

Nos. 159, 160. Both wells are used for irrigating orchard by means of pipe-lines laid. Area is not given, but owners say that each well, if all the water is applied and used with pipe and hose, applying only to trees, would water from 15 to 18 acres. One well was contracted for at 75 cents, the other at 80 cents per foot. The cost was $793.10 and $852.52, respectively.

No. 161. Is cased 350 feet with $3\frac{1}{4}$ and $2\frac{1}{2}$ inch pipe. The water is piped to the highest point of the owner's land and there runs into a small reservoir. The strata passed through are:

	Feet.		Feet.
Surface	26	Clay	260
Blue-clay and shale	62	Sand-rock	269
Blue sand-rock	110	Very hard sand-rock	270
Clay	115	Clay	310
Sand-rock	120	Water-rock (flow, 3 gallons)	315
Clay	142	Clay and sand-rock	350
Shale	151	Water-rock (flow, 35 gallons; temperature, 61°)	370
Clay and shale	158	Clay	377
Water-rock (flow at 177, 1 gallon per minute)	180		

No. 163. In Littleton. Cost, $360. Not cased at all; 16 stove-pipe is all there is in it. Used for water service. There are nine flowing wells in this town, Littleton.

No. 172. Cased to 165 feet, with $2\frac{1}{2}$ inch casing. The formation is:

	Feet.		Feet.
Surface	48	Sand-rock (2 gallons per minute)	243
Blue clay	58	Blue clay	288
Sand-rock (1 gallon per minute)	185	Sand-rock (5 gallons per minute)	291
Shale and blue clay	240	Blue clay	298

No. 174. Cost, $287. Flow is increasing. Has increased 5 gallons per minute.

No. 175. Cased 246 feet.

	Feet.		Feet.
Surface material and blue clay	70	Water-rock (5 gallons per minute)	320
Blue sand-rock	83	Sand-rock	329
Clay and sand-rock	95	Clay	333
Blue clay	136	Water-rock (8 gallons per minute)	335
Sand rock	{ 140 / 254	Iron pyrites	$335\frac{1}{2}$
		Sand-rock	393
Water-rock (1 gallon per minute)	260	Water-rock (12 gallons per minute)	400
Blue clay	281	Sand-rock	424
Water-rock (3 gallons per minute)	285	Water-rock (20 gallons per minute)	431
Blue clay	314	Sand-rock	467

No. 176. Cost, $559.13. Casing of $3\frac{1}{4}$ inch is down 300 feet, of $2\frac{1}{2}$ inch to bottom. The latter projects 15 feet into the $3\frac{1}{4}$-inch pipe. The bottom 80 feet is perforated to admit the flow. The strata passed through were:

	Feet.		Feet.
Surface	47	Clay	390
Blue clay and sand-rock, alternately	242	Water-rock (7 gallons per minute)	425
Water rock (no flow)	247	Clay	430
Sand-rock	250	Sand-rock	445
Shale	258	Water-rock (10 gallons per minute)	450
Sand-rock and coal	260	Sand-rock	465
Water-rock (3 gallons per minute)	265	Coal	$465\frac{1}{2}$
Sand-rock	300	Sand-rock	$469\frac{1}{2}$
Clay	304	Iron pyrites	470
Water-rock (5 gallons per minute)	306	Sand-rock (water 16 gallons per minute)	495
Clay	377		
Sand-rock	381	Clay	500

No. 179. Cost $1,092. Was first sunk to 378 feet; then cleaned out and sunk to 525 feet. Captain Campbell reports 31 gallons per minute as flow.

No. 181. Temperature 62°. Mayers reports the well as flowing 3 gallons per minute.

No. 193. This well is the first one put down in Douglass County, and secured the $200 premium offered by the county commissioners to the one who should first find flowing water in the county.

No. 194. About half-way between Acequia and Sedalia.

From 80 feet water came to within 15 feet of the surface. The flow comes from between 400 and 440. Mr. Kemp says there has been no decrease; if anything, the flow is stronger.

"It irrigates the house-yard, about 300 trees, and vegetable garden; in all about two acres. It has given the best, or as good, results for irrigation as any well in the State for its flow. This is due to the water being carried in pipes to almost the exact spot where it is to be used. If it were left to run in an open ditch in a dry time it would not get 100 feet from the well."

No. 195. Cased 100 feet with 4-inch pipe, the remainder with 2½-inch. Is pumped by a windmill into a 75-barrel tank. Is used for irrigating town lots. Water comes to 50 feet of the surface. Pump is down 75 feet. Supply large.

No. 196. Cased with 5 and 3 inch pipe. Water rises to 50 feet of surface. Pumped. Supplies railroad needs.

No. 197. On West Plum Creek, 5 miles south of Sedalia, probably section 36. The most southerly flowing well in the Denver Basin.

Well was sunk for coal, oil, iron, or gas.

The record is as follows:

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Black adobe	10	10	Brown clay with sand	5	238
Liquid clay	4	14	Brown sand	13	251
Conglomerate	40	54	Brown clay	1	252
River sand	10	64	Hard brown sand	10	262
White clay	5	69	Mineral paint	1	263
Clay and sand	4	73	Hard brown sand	20	283
Heavy conglomerate	5	78	White clay	15	298
Green shale	5	83	Hard sand	5	303
Yellow sand	6	89	Clay and sand	70	373
Clay and sand	37	126	White sand	20	393
Yellow sand	5	133	Gray sand	15	408
Brown clay and sand	20	153	Quartz sand	19	427
Brown sand	2	155	Clay and sand	45	472
White clay	3	158	Greasy clay	2	474
Brown sand	15	173	Oil sand	2	476
Sand mixed with iron ore	5	178	Clay and sand mixed	2½	478½
Sand and gravel	30	208	Clay and sand alternately	40	518½
Lava sand (water 12 gallons per minute)	10	218	Oil sand	2	520½
White clay	5	223	Clay	7	527
Green shale	10	233	Clay and sand alternately	53	580½

Clay, sand, and shale alternately. Some iron ore at 595 feet.

Between 735 feet and 850 feet there are about 80 feet of good iron ore (magnetic oxide) running about 40 per cent. iron.

A few layers of iron pyrites.

There were two lines of casing used in this well and two liners.

Depth of well about 1,500 feet. It was never actually measured.

This well was sunk by A. P. Swilzer, Denver, Colo., in 1887.

No. 198. At first the water came to 24 feet of surface. Now 50 feet. Cost was $1,300. The strata were—

	Feet.		Feet.
Surface and sandstone to	100	Gray rock with hard blue streaks	562
Rock	150	Sand and gravel	600
Clay	412	Black slate	700
White sandstone (water)	462	Clay, etc	900

No. 199. Cost $1,200. Located close to Arvada. "Elevation too high for flow." Water stands at 60 feet from the surface. Supply never tested except with the drilling pump, which failed to lower the water.

On section 17, on the divide between Clear and Ralston Creeks, two wells were sunk, one to 650 feet. Water came to 50 feet of surface.

No. 200. Cost $235. Contracted the drilling for 50 cents per foot.

No. 201. Water flows only about 1 gallon per hour. Is strongly impregnated with sulphur and iron. Mr. Mayers reports that it frequently turns black in the pitcher, again turning clear.

No. 202. The price paid for drilling was $1 per foot for first 100 feet, 25 cents for each 100 feet; 2-inch bore. Total cost, $800. The strata were—

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Drift	36	....	Indurated clay	12	97
Shale	18	54	Sand slate	41	138
Coal	1	55	Iron	3	141
Shale	12	67	Shale	25	166
Coal	(*)	....	Coal	5	171
Black shale	16	84	Clay	25	196
Coal	(†)	....	Sandstone and clay	(‡)	(‡)

* 8 inches. † 10 inches. ‡ First flow of water.

There is another flowing well near by.

In section 30, township 3 north, range 69 west, near Longmont, is a well 250 feet deep, $2\frac{1}{2}$ inches in diameter, which has a flow of alkali water from 25 feet so strong that cattle do not like it.

At Hygiene, west of Longmont, J. W. Goss sunk a well 965 feet deep. The formations passed through were—

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Surface and soap-stone	17	17	Shale	132	416
Coarse sand-rock	33	50	Sand-rock	26	442
Slate	80	130	Fire-clay	2	444
Fine white sand-rock	30	160	Sand-rock and coal	80	524
Shale	30	190	Sand-rock	65	589
Sand-rock	8	198	Fire-clay	2	591
Fire-clay	2	200	Coal	14	605
Coal (supposed)	4	204	Sand-rock (bearing oil)	300	905
Sand-rock (oil-bearing)	80	284			

The water flowed from 675, but soon ceased, supposed to be due to gas.

No. 203. Some 16 miles east of Denver, and some lower, bored with a diamond-core drill:

	Feet.		Feet.
Clay	12	Coal, some shale	267
Soap-stone, with thin streaks of coal	98	Soap-stone	271
Sandstone	112	Sandstone	293
Soap-stone	121	Soap-stone, some coal	321
Sandstone	133	Sandstone	361
Soap-stone	147	Soap-stone	380
Soap-stone, thin streaks of coal	158	Sandstone	390
Coal, streaks of shale	173	Soap-stone, shale, thin seams of coal	465
Soap-stone, streaks of coal	220	Shales	700
Sandstone	241	Hard gray rock	702
Sandstone, seams of coal	256	Shales	$800\frac{1}{2}$
Soap-stone	260		

United States Signal-Service office, Denver, Colo.

[Precipitation at Denver, Colo., December 1, 1871, to May 31, 1890.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total yearly.
1871	......	......	......	......	......	......	......	......	......	......	......	0.51	......
1872	0.55	0.22	1.71	2.09	3.74	2.07	2.69	1.65	1.57	0.68	0.69	0.29	17.95
1873	0.13	0.24	0.22	2.43	0.75	2.24	2.00	1.41	0.89	0.73	0.16	0.53	11.73
1874	0.84	0.53	0.49	1.70	2.43	1.21	3.35	0.68	1.34	0.64	0.08	0.17	13.46
1875	0.38	0.60	0.39	2.24	1.94	0.43	4.12	1.97	2.89	0.22	1.28	0.59	17.05
1876	0.21	0.11	1.80	1.22	8.57	1.10	1.16	2.03	0.60	0.12	1.50	1.70	20.12
1877	1.90	0.40	1.40	2.77	2.30	1.93	0.33	1.30	0.38	2.15	0.73	0.79	16.38
1878	0.10	0.48	1.82	0.05	2.90	2.78	1.38	2.25	1.23	0.80	0.67	1.05	15.51
1879	0.40	0.39	1.00	2.62	3.36	0.32	0.64	1.38	0.02	0.19	0.21	0.33	10.86
1880	0.38	0.32	0.21	0.31	1.11	1.22	1.38	1.46	0.89	1.37	0.83	0.10	9.58
1881	0.50	1.22	0.87	0.50	2.21	0.09	2.50	2.33	0.57	0.32	1.68	0.00	12.79
1882	0.57	0.20	0.20	1.47	2.98	4.96	0.66	1.20	0.06	0.75	0.71	0.73	14.49
1883	2.35	0.45	0.21	3.10	4.30	0.85	2.27	0.75	1.08	1.49	0.32	2.32	19.49
1884	0.22	0.86	0.93	3.33	4.61	1.47	0.65	1.71	0.13	0.21	0.19	0.76	15.07
1885	0.41	0.75	0.97	4.94	2.13	0.66	1.33	1.18	1.22	0.73	0.55	1.08	15.95
1886	0.62	0.72	2.36	2.79	0.09	2.26	0.50	1.62	0.98	0.33	1.93	0.87	15.07
1887	0.67	0.30	0.23	2.16	1.13	0.53	2.49	2.68	0.97	0.97	0.22	0.14	12.49
1888	0.11	0.37	1.15	1.71	2.66	0.29	0.41	1.51	0.11	0.77	0.33	0.09	9.51
1889	0.50	0.70	0.40	1.34	3.44	1.88	2.94	0.33	0.28	2.11	0.53	0.30	14.75
1890	0.18	0.46	0.35	2.50	2.01	......	......	......	......	......	......	......	......
Total	11.02	9.32	16.71	39.27	52.66	26.29	30.80	27.44	15.21	14.58	12.61	12.35	26[illegible]
Normal	0.58	0.49	0.88	2.07	2.77	1.46	1.71	1.52	0.84	0.81	0.70	0.65	14.57

THE GREELEY BASIN.

The Greeley Basin is very different in character from the Denver Basin. As far as the borings have gone, and they have penetrated 240 feet, the formation is entirely blue shale, with occasional seams of sand-rock.

LIMITS.

The basin joins the Denver Basin on the north and includes the South Platte River and its tributaries with certain limitations, from Platteville to some point, as yet undetermined, a short distance below Greeley.

From Platteville the boundary between the Denver and Greeley Basins seems to extend northwesterly across the lines of drainage to the foot-hills. On the west the basin is bounded by the foot-hills, the shale passed through by these borings coming to the surface and forming the plains at the base of the foot-hills. Sandstone of formation below the shale constitutes the foot-hills themselves. The basin then includes portions of Larimer and of Weld Counties, and portions of several of the districts established by the State legislature for administration of water, viz, portions of water districts Nos. 2, 3, 4, 5. A large portion of this subdistrict is well supplied with irrigation canals, and having good streams from the mountains, it is not profitable to expend a large amount upon subterranean water for irrigation purposes.

The eastern portion of the district, however, has need of good water for domestic purposes, especially in the periods of low water in the streams. It is to supply this domestic water that the wells in this district have been sunk.

NUMBER OF WELLS.

In this basin 12, or counting Stout, 13 wells have been sunk; 8 are in Greeley; 1 at Evans, 4 miles south of Greeley; 1 in Eaton, 8 miles north; 1 near Windsor, 12 miles west; 1 in Loveland, 20 miles south of west, and about 4 miles from the foot-hills. The one at Stout is to the west of the Greeley Basin in the sandstone beneath the shale.

Of these, all are flowing wells except the one at Eaton and the one at Windsor.

The flow is nearly the same from each well in the basin, from 1 to 1½ gallons per minute. The water is of a character desirable for domestic use, but is injurious to vegetation, and therefore undesirable for irrigation. With the water is a small flow of illuminating gas, in sufficient quantities at Loveland to maintain a constant flame. Though this seems to be a true basin it is doubtful if the flow observed is genuine artesian. The hydrocarbon gas present is subject to a pressure equivalent to a column of water 116 feet high or to a pressure of 500 pounds per square inch. This great pressure would cause a large amount to be held in solution. With the less pressure to which the water in the upper portion of the tube is subjected, some of this gas in solution will be given off, and gas not dissolved will expand in proportion as the pressure is removed. The consequence will be that a flow of water will be caused due to the expansion of the gas.

THE GREELEY WELLS

Are 8 in number and are of the same character; they pass through the same strata, and have the same flow and cost about the same.

The following facts were obtained principally from a letter by Dr. G. Law, of Greeley:

There are 8 artesian wells in the town of Greeley, 1 owned by the city of Greeley, 1 by the proprietor of the Oasis Hotel, 6 by as many different corporations of citizens. The City Well was the first one bored, in 1883, and being an experiment was expensive, costing in the aggregate nearly $10,000. Starting from the surface, 4 feet of soil, 31 feet of almost pure sand and gravel, 1,125 feet of bluish-gray shale, 40 feet of soft grayish sandstone. When this sandstone was struck a very powerful odor of

rancid fish-oil and a small flow of illuminating gas, together with a small amount of a dark thick tarry oil having a fishy taste, soluble in ether and saponifiable when boiled with the caustic alkalies.

When the 40 feet of sandstone was bored through water flowed to the amount of 2,000 gallons during the twenty-four hours. Tested by its capacity to dissolve soap it is very soft. The city council sent a sample to Ann Arbor, Mich., and had it properly analyzed. The analysis showed that a gallon contained 89 grains of solids, principally bicarbonate of sodium and common salt.

This water was found to be a desirable one for domestic purposes. In the hope of obtaining a better supply the sinking of the well was continued until a depth of 2,260 feet, through substantially the same bluish gray shale, but no additional flow of water was obtained. The only difference in this lower shale from that above the water-bearing sand was its constant impregnation with the fish-like oil above described and an increase in the amount of inflammable gas emitted.

The work of sinking was stopped because of the expense incurred. The 1,060 feet below the water-flow was filled up with gravel and the well properly cased and packed to exclude the surface water down to the bottom of the water-bearing sandstone, and now gives a flow of 2,000 gallons per twenty-four hours. The seven wells bored afterward were all sunk 1,200 feet only, and all obtained substantially the same water as to quality and amount.

Mr. Hunter, the owner of the Oasis well, found the flow from his well to be entirely inadequate for his purposes. Hence he put down a pump, operated by steam-power, with the working-barrel 800 feet from the surface, and commenced to raise from 400 to 500 barrels of water per day. In less than a week this stopped the flow of all the wells. The city put down a hand-pump in its well and with the working-barrel 75 feet deep, which has been in use ever since, and yields more water than the natural flow ever did. Company No. 2 put in a hand-pump, which gives for two days' pumping by one man a week's supply of water to twenty-five families for household and domestic use. At the present the Oasis pumps by steam-power all the water they want—usually about 400 barrels per day.

Nos. 3 and 4 hire power from the city water-works and pump by means of a water-motor. No. 6 uses a wind-mill, with elevated tank. Nos. 2 and 5 have connected their pipes and jointly pump No. 5 well by a water-motor actuated by water taken from the city mains.

The city well and No. 2 are 8-inch holes; No. 1 was a 5-inch hole, and was spoiled by exploding a torpedo of nitro-glycerine in the sandstone in the hope of improving the flow, and was abandoned. All the others are 6-inch holes. The 8-inch wells did not give an appreciably larger flow than the 6-inch.

The average cost of all the wells, after the experimental one by the city, was, when completed, about $2,500.

The Evans well was likewise put down by the town. No record could be obtained of it, but the contractor, who also bored the Greeley wells, says that it is a duplicate of them, except that it struck the water stratum at 1,125 feet. As Greeley and Evans are at the same elevation, this indicates a dip to the north of about 8 feet to the mile.

The Loveland well was sunk in 1885 for the purpose of procuring water for domestic purposes for the town. Money was raised by bonds—$10,000 in all. Interest is still being paid on $8,000. Water was obtained at 1,340 feet, about 1½ gallons per minute. Hoping to get a better supply the well was extended to 2,465 feet, but unsuccessfully. The formations passed through are as follows:

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay and gravel	40	40	Sandstone (flowing water and gas)	25	1,365
Blue shale	395	435	Blue shale	95	1,460
Sandstone	25	460	Sandstone	30	1,490
Blue shale	640	1,100	Blue shale	145	1,635
Sandstone	30	1,130	Black sandstone (crude oil)	2	1,637
Blue shale	210	1,340	Blue shale	825½	2,462½

Water is obtained at Loveland at 180 feet greater depth than at Greeley. Loveland has 335 feet greater elevation, consequently the water-bearing stratum is about 155 feet lower at Greeley than at Loveland; or, as the distance is about 20 miles, the dip is between 7 and 8 feet to the mile, to the north of east. Near Windsor, which is halfway between Greeley and the foot-hills, R. Loveland sunk a well in 1887 to a depth of 350 feet, at a cost of $580. Water in considerable quantity, which came to within 10 feet of the surface, was struck at 60 feet. This was very hard and was cased off. Water was again struck in sandstone at 250 to 350 feet, which rises to within 18 feet of the surface. The quantity is small, but is as soft as rain-water.

Eaton is nearly 200 feet above Greeley. The well sunk there by Governor Eaton struck water in great quantity and of remarkable purity at a depth of about 230 to 260 feet, which came to within 20 feet of the surface. The water is of different quality, and comes from a formation above that of Greeley. More water was found at about 400 and at 625 feet. The boring was continued to 970 feet. No success has attended the efforts to get a copy of the record of this well. The depths above given were furnished by the contractor.

At Platteville, on the southern limit of the basin, Mr. Hopkins, in sinking a coal shaft, cut a large underground supply of water.

At the same place, 1½ miles southeast of line, an underground stream of water was bored into in 1868 at a depth of about 30 feet. The width of the stream is unknown. It has a depth of 4½ feet. It flows to the northwest with a strong current, which makes a perceptible noise at the surface.

Stout is properly outside of the Greeley basin, but it is very close to the border and may be considered here. It is just within the first range of foot-hills, and is in the sandstones which underlie the thick shales of the Greeley basin. The well was sunk by the Union Pacific Railway, which owns extensive quarries at that point, principally as a prospect hole. The boring is almost entirely in sandstone of varying qualities for the full depth of 1,225 feet. At 922 feet water was encountered, flowing 40 gallons per hour. This increased in quantity until at 1,000 feet the flow was doubled. The pressure is sufficient to raise the water some 30 feet.

The water carries some 150 grains of solids to the gallon—too much to render it fit for boiler use.

THE LOWER PLATTE.

This subdistrict includes the Platte Valley from the vicinity of Greeley to the limit of the division, *i. e.*, to the one hundred and third meridian.

This subdistrict therefore includes portions of the counties of Weld, Morgan, Washington, and Logan, and of water districts Nos. 1 and 67.

The Platte which furnishes the water for this region, is a stream, especially at the lower portion of this district, presenting more stretches of sand than water for the greater part of the year.

But while invisible at the surface, water is always present in the sand. Settlements are confined almost exclusively to the vicinity of the river. Little attempt has been made to go out upon the uplands, where water is found at moderate depths. But one or two attempts have been made to find flowing wells, or to sink deep ones.

Farming is carried on exclusively by irrigation where water can be had. There are several flourishing communities at Fort Morgan and Sterling along the river.

Starting near Greeley and descending the river the principal ditches we meet in order are the Kiowa and Bijou; the Weldon Valley; the Fort Morgan; the Platte and Beaver; the Platte and Beaver Supply; the Pawnee; the Sterling No. 1; the Iliff, each from 15 to 58 feet wide, and from 5 to 50 miles long. There are numerous smaller ditches. These are subject to scarcity of water in most seasons, but are frequently aided by floods coming down from the divide through the dry stream beds.

At Sterling the town attempted to sink a well in the spring of 1890, but on account of trouble with the contractor the well is at a standstill. The reports received are very conflicting. Blue slate or shale was struck at 85 feet. Water rose to 2 feet of the surface. This water is soft and abundant, and carries 24 grains solids to the gallon, while the surface wells have 72.

At Keota, on the Cheyenne line of the Burlington and Missouri Railroad, water is obtained from a well 148 feet deep. It is found in a layer of sandstone 20 feet thick, which was struck after passing through magnesia rock and blue clay principally.

At Grover, water is struck in quicksand at a depth of 78 feet below the surface.

PUEBLO AND FLORENCE.

These two districts are for convenience put together, although the characteristics are different. This subdistrict includes the Arkansas River and its tributaries (save the Fontaine qui Bouille) from Cañon City to Pueblo. The former is almost within the mountains. The subdistrict is about 40 miles long. It includes a portion of Pueblo and of Fremont Counties.

This district includes the oil region of Florence, which supplies most, if not all, of the oil used in the Rocky Mountain region.

Oil was obtained in the early mining times from a shallow shaft on Oil Creek. It was in the hope of striking the oil flow that all the wells, with few exceptions, in this subdistrict were sunk. Clark's well was bored at Pueblo in 1879, and his was the first in the state to strike flowing water.

There are now eight wells at Pueblo—one abandoned—flowing from 1 to 80 gallons per minute, averaging about 20.

Near Florence there are four known as flowing wells. At a low estimate there are a hundred oil wells. From one point I counted thirty-seven derricks through the trees. Of these wells, many struck flowing water, but cased it off. Of the few whose flow is known, the flow averages nearly 200 gallons per minute. This is, undoubtedly, above the average, as these include the exceptional ones whose flow was noteworthy.

The Pueblo wells are used for domestic and medicinal purposes. The water of each has individual characteristics, as the analyses show. Bath-houses are erected in connection with three wells. A business is made of shipping the waters of one well.

The waters of the Florence wells run to waste.

The Pueblo deep wells are strongly impregnated with iron, the shallower wells with soda, though in either case not sufficiently to be unpalatable. In neither Florence or Pueblo is the water likely to prove of importance to irrigation. At Pueblo the flow is too deep and too small; at Florence, while the flow is greater, the cost is still relatively greater.

INDIVIDUAL WELLS.

PUEBLO.

The Clark mineral spring well was the first well in Colorado to strike flowing water. It is located in South Pueblo, in the river bottom. It was begun by O. E. Clark, a Pennsylvania oil man, in search for oil. The well was begun in 1879; water was found January 1, 1880. The total depth is 1,412 feet; the water comes from 1,166 feet. In June, 1881, the pressure was 60 pounds per square inch, the flow 126,000 gallons per day. The proprietor claims no change in flow since then.

The water of this well is used for bathing and medicinal purposes, it being claimed that it has curative effects on various diseases, including diabetes. It is said the water contains bicarbonate of sodium, sulphite of sodium, sulphate of magnesia, manganese, potassium, sulphuric acid, arsenious acid, iron, etc.

The strata of this well represent the formation of this region.

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil and gravel	34	34	Shell and sand-rock	15	1,045
Blue shale	24	58	Soft black shales	103	1,148
Black shale (having oil and gas)	572	630	Shell and sand-rock	10	1,158 / 1,166 / *1,180
Hard shell and sand-rock	20	650	Black shales	15	1,195
White sand-rock	40	690	Coarse sand-rock	35	1,230
Black shales	10	700	Purple shales	10	1,240
Soft coarse sand-rock	35	735	Sand-rock	30	1,270
Black shales	165	900	Purple shale	....	1,400
Shell and sand-rock	40	940			
Black shales	90	1,030			

*Mineral water in red rock.

The well of the Colorado Coal and Iron Company is on the mesa south of the Clark well and is some 100 feet higher. Mr. de Schweinitz, of this company, states that, allowing for the difference of elevation, the strata are almost identically the same as in the Clark well. This well is sunk to 1,260 feet and secures a flow of from 20 to 25 gallons per minute, which does not seem to have materially changed. At present the water runs to waste, though it supplies water for domestic use to the vicinity and to a neighboring smelter.

The Mineral Park well, also on the mesa, was sunk in 1881. The depth is doubtful, but is reported to be 1,150. The flow on June 2 was 3 gallons per minute, used for bathing.

The Columbia Heights well, section 9, township 21 south, range 65 west, was sunk in 1887 by a suburban company for domestic purposes. Total depth 789 feet. A small flow was struck at 516; the second flow was reached at 779 feet. The two flows combined yield about 8 gallons per minute. The strata passed through are the following:

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil	23	23	Water sand (first flow small)	100	616
Gravel	8	31	Black slate	163	779
Shale	59	90	Water sand (second flow)	10	789
Lime	15	105			
Black slate	411	516			

Cased 532 feet with 5$\frac{5}{8}$-inch casing.

The water has a trace of soda. It is running to waste.

The well of C. H. Small on section 17, not far from the last, was sunk 772 feet in 1888, securing a flow of 2½ gallons per minute. It is now being sunk to 1,200 feet to secure a larger flow.

The strata are as follows:

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Black alluvial soil	12	12	White sandstone	80	575
Blue shale	60	72	Black slate	90	665
Limestone	10	82	Red rock	95	760
Black slate	413	495	Gray sand	12	772

The Fariss House well is situated in Pueblo, north of the river, in block 58. It is said to be 1,400 feet deep. Its pressure when struck was 60 pounds per square inch. The water is mineral, but, like all the waters of the Pueblo wells, is very agreeable to the taste. It is connected with a bath-house as well as with the hotel. All pipes were shut off, and the whole flow, as measured in a bucket, June 2, 1890, was 13 gallons per minute.

The analysis is given later.

The North Pueblo Heights well, put down by a suburban company, was sunk 1,820 feet, striking small flows at 1,200 feet and at the bottom. This well is north of Pueblo on section 12, township 20 south, range 65 west. It was not visited, but reports were that the flow was about 1½ gallons per minute.

A well, known sometimes as McLeans, was sunk 9 miles west of the town and 4 miles south of the river, on Bogg's Flat. The well was abandoned, as oil was not found. Little information could be found. J. T. Drake, present owner, recalls that the driller reported water several times.

FLORENCE.

One well belonging to the Consolidated Oil and Land Company was sunk in 1884 in section 13, township 19 south, range 69 west, to a depth of 780 feet. The strata, as given from recollection, were 3 feet of wash, 13 of sand; then alternate streaks of sand, limestone, gypsum, and slate to 425 feet; then 300 feet slate; gas at 725; warm soda water at 730; then gneiss and granite. The flow was 1 gallon per minute.

On section 14 of the same township the Florence Oil Company struck a flow of soda water at about 1,000 feet. The flow is between 400 and 500 gallons per minute. This flow the drillers did not succeed in casing off, so the well was abandoned. Another was sunk 150 yards distant, which struck a flow of less strength. The water is about 90 degrees temperature, strongly impregnated with iron and soda.

The Cañon City Oil Company's well No. 1, section 23, township 18 south, range 78 west, was sunk in 1883. The whole depth was 1,600 feet. Flowing water was found at 280, at 699, and 1,150; at the latter depth it was the strongest. The flow seems to have been from 400 to 500 gallons per minute. The pressure was sufficient to cause the water to stand nearly 100 feet above the surface. The well was abandoned.

The following is an extract from an article by Judge Felton, published at the time:

> We had heard that there was quite a flow of warm water, but had not comprehended the magnitude of it. The hole of the well is 8 inches in diameter and the water was pouring out with such force as to bring up with it, from a depth of 1,220 feet below, stones weighing from 2 to 4 ounces each. The water flowing onto the

level land near the derrick, covered a large tract of land and as it went on formed into several small streams and thus flowed into Oil Creek. The water, if all together, would make quite a good sized creek.

We took a thermometer with us and found that the water stood at 90°. There is some iron in the water, as is evident from the iron stain produced wherever it runs. The flow of water, as calculated by men at the well, is 100 gallons per minute.

At a depth of about 400 feet a vein of flowing sulphur water was struck. That was cased off and another 400 feet sunk when another vein of water was struck, and then between 1,100 and 1,200 feet this vein was tapped.

The formation is reported to be as follows:

Strata.	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Drift, adobe, and gravel	20	20	
Shale	260	280	Flowing water from sandy shale.
Shale, hard and soft, with layers of limestone.	370	650	
Limestone	45	695	
Sandstone	4	699	
Thin band of shale	....	......	
White sandstone	23	722	Second flow ten times the first.
Shales, lime, and sandstone	408	1,130	Flow of water almost uncontrollable.
Shales and sandstone	270	1,400	
Soft shale	....	1,600	

On attempting to extract the casing at the end of a few months it was found to be so eaten as to be worthless. Dr. Drake says that grass keeps green the whole winter from the moisture caused by waste of this well.

Directly north of Cañon City the State penitentiary in running a tunnel for an irrigation canal struck a heavy flow of water, quantity unknown, in the sand-rock.

Judge Fulton reports soda springs, both hot and cold, in that vicinity.

Mr. Meredith, of Rye, Colo., writes:

I am not able to give you the information that you request in the inclosed circular, from the fact that there has not been any artesian wells sunk in the western part of Pueblo County. There are numerous quite large springs near the foot of Greenhorn Mountain, with several small streams of water running out of the mountain. The largest of these is the Greenhorn Creek; second, Grenaros; and Muddy, with different branches of the St. Charles. Further north the Greenhorn Mountain rises to an altitude of 10,000 feet. On top of the mountain there are several lakes of water and thousands of acres of swampy land. It has always been my impression that artesian water could be struck at a reasonable depth that would give large flows of water. Individual farmers can not afford to experiment, but if provision could be made for sinking an experimental well somewhere near the foot of the mountain the farmers would then know whether they could stand the expense or not. The creeks named furnish water to irrigate to any great extent only while the snow lasts.

THE LOWER ARKANSAS.

This subdistrict includes the Arkansas Valley from Pueblo to the limits of the division, including portions of Pueblo, Otero, and Brent Counties.

This district is comparatively little settled. Rocky Ford may be considered as the only agricultural community of any age. Canals in this valley are all, with the exception of a few minor ones, of recent construction; but at present development of this character is being rapidly pushed forward. Several large canals on each side of the river are being constructed.

FLOWING WELLS.

There are no flowing wells in this subdistrict, and only one attempt, which was the unsuccessful one made by the Government, near Fort Lyon. This well was sunk to a depth of nearly 800 feet.

At Coolidge, Kans., there is a group of wells, some of them inside the Colorado line, but outside the division assigned me. Water is obtained here at a depth of about 300 feet. Farther west, Mr. Koen, of Lamar, is at present sinking two wells, one of which at last report was down 100 feet.

THE DIVIDE.

This sub-district includes the divide between the Platte and the Arkansas Rivers, embracing the counties of Elbert and Lincoln and portions of Douglass, El Paso, Weld, Morgan, Washington, Arapahoe, Kit Carson, Cheyenne, Kiowa, Otero, and Pueblo.

The elevation varies from 7,000 to 4,000. Passing from north to south on the one hundred and fourth meridian, the center of this district, the rise is from 4,300 on the Platte to about 6,200 feet at the summit 80 miles south, and it then descends to 4,400 feet in the valley of the Arkansas.

From east to west, following the highest ridge, the rise is from 5,000 feet at the 103rd meridian to over 6,200 at the 104th, and 7,300 at about 104° 30′. The portion near the mountain is much broken. Except in the valley of the Fountain there is no agriculture to speak of in this area. Some of the small creeks near the mountains furnish water for irrigation. On the divide itself, as at Easton and the northeastern part of El Paso County and the western part of Elbert, fair yields of some crops are secured without irrigation, and the area compared with the whole area under consideration is insignificant. There are few settlers. The streams, which are frequently perennial at or near their head, soon disappear in the sands, and appear only as an oleated pool or stretches of running water, if they appear at all. Three deep wells have been sunk in this area, one at Colorado Springs, one at Calhan, near the summit of the Rock Island Railroad, one at Akron, Washington County, one at Scranton, Arapahoe County, on the borders of the Denver Basin. The Colorado Springs well was sunk in 1885 to a depth of 1,120 feet. No water was found below the surface water, which was at the level of the Fountain. The first 65 feet consisted of sand and gravel, the lower 35 of this being filled with surface water. The rest was blue shale without interruption. Above 600 the shale stands atmospheric influences, while below it does not.

Record of well at Calhan, Colo., 1888–'89.

[Record furnished by W. R. McFarlin, of the Chicago, Kansas and Nebraska Railroad.]

Strata.	Thickness.	Depth.	Strata.	Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand	28	28	False coal	1.02	337.09
Sandstone	10	38	Micaceous sand shale; one-half inch coal at 360 feet	23.07	361.04
Dark sand shale	25	63	Soapstone	54.09	416.01
Clay and sand shale, turning into soft sandstone	78.10	141.10	Micaceous sand shale	16	432.01
Soapstone, with thin streak of coal at 232 feet	113.02	255	False coal	2	434.01
Soapstone and shale in thin layers	51.06	306.06	Poor coal	1	435.01
Sandy limestone	7.10	314.04	Clay shale and soapstone	45.05	480.06
Sand shale, with thin streaks of coal	8.08	323	Sandy false coal	4	484.06
False coal	1	324	Poor coal	2.06	487
Fire-clay	1.06	325.06	Micaceous sand shale, with some clay shale	59.01	546.01
Dark clay shale	3.06	329	Sandy false coal	5.01	551.09
Sand shale	7.07	336.07	Dark clay shale	4.09	556.06
			Mixed sand and clay shale	9.06	566

At Scranton, sec. 16, T. 3 S., R. 65 W., the well was sunk to 800 feet 6 inches in prospecting for coal. No flowing water was struck. Other water was not reported. The formation consists of soapstone, sandstone, shale, and streaks of coal to the full depth.

At Akron a well was put down by the Government. Water in fair quantity was found at 1,155 feet, which came to within 55 feet of the surface. The Burlington and Missouri Railroad Company secure water at the same place from sand at a depth of about from 75 to 84 feet. This is from a dug well of about 100 feet deep, and gives about 1,000 gallons of water per hour.

At Otis, 12 or 15 miles east of Akron, a boring was made to 2,400 feet, but without finding flowing water.

The following is the record:

	Feet.
Surface	0 to 206
Shale mixed with sandy shale	206 to 1,400
Shale or jointed clay	1,400 to 1,500
Shale	1,500 to 2,000
Shale mixed with fine sandy shale	2,000 to 2,200
Shale, some harder	2,200 to 2,400

The strata was about level, and when the cores were taken out they split in pieces, making cylindrical pieces about the thickness of a silver dollar, almost perfect; no water.

At the same place the Burlington and Missouri Railroad gets water from a dug well about 100 feet deep. The supply is quite large, though it has never been tested.

At Corona sufficient water is found for railroad purposes at from 65 to 70 feet.

At Barr the Burlington and Missouri Railroad Company dug a well 125 feet deep and bored down 100 feet farther, making a depth of 225 feet in all. The water flows into the bottom of the well in quite large quantities.

THE WATER SUPPLY ALONG THE LINE OF THE MISSOURI PACIFIC, EAST FROM PUEBLO, IN COLORADO.

[From an interview with the Superintendent at Pueblo.]

From Pultney to Arlington good water is not found as far as has been tried, which has been only to depths of less than 40 feet. At Sheridan Lake a hole was bored 1,400 feet deep. Water raises to within 400 feet of the surface. None of these wells but can be exhausted. The Arlington well yields about 50,000 gallons in twenty-four hours, but most wells yield only about 20,000.

The Galatea well yields only 4,000 or 5,000 gallons daily. One mile north, at a depth of 11 feet, so much water was struck by a man digging a well, that he had to stop. The experience of the Missouri Pacific is that wells are better and shallower in Colorado than in Kansas.

Horse Creek is dry where it is crossed by the Missouri Pacific.

Adobe Creek at Arlington has never been known to be dry. It is the only running stream that the railroad crosses after leaving the Arkansas, until it reaches the Smoky.

The following are replies to inquries in the northeastern counties of Colorado:

J. Williams, of Yuma, well-driller, reports:

Arapahoe County (*eastern portion*). The soil depth varies from 18 inches to 10 feet. In some places after passing through the soil one strikes magnesia or native lime, in others gravel. Yuma County soil varies near Ourav about 2 feet depth of loamy soil, somewhat mixed with sand, then a white chalky substance to the depth of 200 feet.

Crossing southward over into Arapahoe County, "shale" is struck at a depth of about 200 feet. Crossing over eastward into Dudley County, Nebraska, no water was found at a depth of 300 feet, but the workmen struck blue shale and stopped after getting 10 to 15 feet into it.

North of the town of Yuma, about 9 miles, there is a good rich top soil 2 to 4 feet, then magnesia or native lime and strata of magnesia and gravel alternating, about every 5 feet, a white chalky substance like marl 5 feet in thickness was struck in several places. Water is found at an average of 190 feet.

At Eckley, a sandy loam section, I struck water at a depth of 34 feet in quicksand.

In Dunn's addition, at Yuma, a loamy soil of 2 to 4 feet, depth at 165 feet, first sheet of water; at 185, second sheet of water was reached.

In *Phillips County* I passed through black gravelly soil and thin whitish gravel, with sand mixture, to 242 feet, when water was found. Well was completed at 257 feet.

In *Logan County*, at 9 miles northeast of Rockland, limestone soil for about 5 feet, then magnesia intermixed with great lumps to depth of 40 feet, then alternating strata of magnesia and gravel, and sand of about 10 feet each to a depth of 195 feet, when water was reached.

He also reports that he never struck a point in eastern Colorado where he could not find water; while he failed to do so in Nebraska and Kansas. There it runs in veins; in Colorado it lies in sheets. He believes that as there is so great a variety in the strata here we may at some point strike artesian water.

E. K. Green, Le Roy post-office.

I know of no artesian well within 150 miles. My well is 3 feet in diameter and is at a depth of 141 feet, and curbed with pine board its whole length. I have about 10 feet of water and draw it with a hose and 22-gallon barrel. I think if I were to dig from 300 to 400 feet I should have flowing water. Last winter on cold mornings it emitted gas.

THE DIVIDE SOUTH OF THE ARKANSAS RIVER.

This subdistrict includes the portion of Colorado south of the Arkansas River. It includes portions of Las Animas, Huerfano, Pueblo, Otero, and Bent counties.

The general slope is northeasterly. In the southwest the elevation reaches 7,000 feet, and from that the elevation varies to from 4,000 to 4,700 along the Arkansas. No flowing wells have been struck in this subdistrict. Three attempts only have been made—one at Thatchers, Las Animas County, on the Atchison, Topeka and Santa Fé Railway; a second at Walsenburgh, Huerfano County, on the Denver and Rio Grande Railway; the third about 10 miles southeast of the latter place, at Rouse Junction. Thatchers is in a valley possibly one-half mile wide, with bluffs on either side. The elevation is about 5,400 feet. The well was sunk 900 feet. Water is found which rises 200 feet from the bottom. No information could be obtained of the formations passed through.

The well at Walsenburgh was bored for oil to the depth of 1,250 feet. The formation was almost entirely shale. Salt water was struck, which came to within 40 feet of the surface.

At Rouse Junction the boring was down 1,180 feet about the middle of May. Salt water was encountered at 1,100 feet, which filled up 500 feet of the well. It was cased off, and the intention was to go deeper for good water. This well is being sunk by the Denver and Rio Grande Railway Company.

THE SAN LUIS VALLEY.

The San Luis Valley or Park is the region of Colorado having the best and most easily developed supply of artesian water, in consequence of which the number of wells have gone into the thousands, and they are fast increasing. These wells are being used as a source of water for irrigation supply, so that while this area may be outside this investigation proper, a consideration of the artesian wells or conditions of the west would be incomplete without a study of those of the San Luis

Valley, which is similar in many conditions to other prospective basins in Colorado and New Mexico.

The information is incomplete and is based on previous personal knowledge of that valley, supplemented by such correspondence as the time would allow.

The San Luis Valley or Park in southern Colorado includes that portion of the Rio Grande Valley which is in Colorado. It is at an elevation of 7,500 feet, but is made a valley by the enormous mountain ranges which surround it.

On the east the Sangre de Cristo range rises abruptly with almost no foot-hills to its full height of 14,500 feet. On the west are the mountains of the continental divide, containing the sources of the Rio Grande. These mountains rise to a less elevation and with less abruptness than those of the east. To the south are rugged hills, some of lava, through which the Rio Grande breaks on its way to the Gulf.

From north to south the valley is some 90 miles long, 45 from east to west. It has an area of about 4,000 square miles, an area as great as that of Connecticut.

The greater part of the valley has evidently been sometime the bed of a lake. The valley is smooth as a floor, with so uniform a slope that the canals all follow the lines of Government surveys. The Prairie canal, for example, thus runs on a section line for 26 miles. Near the mountains the land slopes each way from the Rio Grande, whose bed has been raised by the detritus brought down in floods. A similar fact is more noticeably true of the smaller streams. The raising of the bed has been largely aided by the fact that the smaller streams, some of considerable size, sink and disappear before proceeding far, furnishing probably a portion of the remarkable artesian supply of the valley.

AGRICULTURE AND IRRIGATION.

Notwithstanding the great elevation, agriculture is proving a success in the San Luis Valley. Wheat, oats, barley, peas and potatoes are raised with large yields. Surrounded as the valley is, on all sides by high mountains, the clouds are stripped of moisture and the rainfall is scanty. Irrigation is needed. The ease of constructing canals, the freedom from engineering difficulties, and the large supply of water in the Rio Grande has led to the development of the finest system of irrigating canals in the west. The Rio Grande (formerly known as the Del Norte) canal is 65 feet wide on the bottom, nearly 100 on top, has a main channel 40 miles long, and with its laterals measures some 200 miles.

The Monte Vista or Citizens' Canal, on the south side of the river, is 50 feet wide on the bottom. So is the Empire. The Prairie, the Farmers' Union, and the San Luis are not much smaller, and each measures from 30 to 60 miles of main channel. These canals are all from the Rio Grande. The Alamosa, the La Jara, the Conejos, the Saguache, and the San Luis furnish water for smaller systems of canals, but such is the extent of land that notwithstanding these systems and the large supply of water, there is much more land than there is water obtainable from these sources.

THE ARTESIAN AREA.

Conejos, in township 33 north, has not been successful in finding flowing water. But from Sanford, in the township north, to Saguache, in township 44 north, water is found in abundance and at moderate depths. The basin is roughly oval in shape. It is about 70 miles in

greatest length north and south and about 30 miles in greatest breadth. There is some doubt about the last dimension. It includes some 45 townships, consequently its area is about 1,600 square miles.

NUMBER OF WELLS.

It is impossible to give a reliable estimate of the number of wells in this basin. Artesian wells are so numerous that they cease to attract more than a passing glance, and a reliable count would require a personal visit to the homes of the farmers. It has been difficult to get any information, because of the fact that the wells were so numerous that correspondents dislike to attempt a description or to give a list which must necessarily be incomplete. Finding that a list of the wells could not be procured, attempts were made to procure a list of the contractors, hoping to get a partial list through them.

Capt. C. A. Aldrich, editor of the Monte Vista Graphic, replies:

> Artesian wells in the valley are so numerous, and the contractors such a multitude, that it is a hopeless task to attempt to give anything like a list of either.

The wells, evidently, are a great number. I saw literally hundreds in July, 1889, in the course of a drive over the system of canals of the valley, and since that time the number has more than doubled. W. H. Graves, C. E., superintendent of the two largest canal systems of the valley, says:

> Nearly every quarter section has a well, and some have several.

S. E. Newcomb, of La Jara, has 8; D. E. Newcomb, of the same place, 17; H. H. Marsh, of Monte Vista, 8; the little town of Monte Vista has from eighty to one hundred. The Empire farm, of nine sections, near Alamosa, has 40 wells, and the Excelsior farm has still more. These are 3-inch wells. M. B. Colt, the general superintendent of these farms, as well as of the Empire and San Luis canals and well acquainted with a large portion of the valley, says:

> I will not attempt to say how many of these 3-inch wells there are in this valley, but if I were going to make a guess at it, I should say there were at least 5,000.

This estimate is probably too high. Of the 1,600 square miles which may be considered as constituting the area of this basin a considerable quantity is State land, and thousands of acres still unimproved and unsold belong to the canal companies. After allowing for this, it is still not improbable that the number is 2,000, possibly more.

The greater number of the wells are of 2 or 3 inch bore; many are of only $1\frac{1}{4}$ inch. The 2 deepest in the valley, at Alamosa, are 6-inch bore.

DEPTHS.

The few records at hand seem to indicate that the depth to first flow is less in the southern part of the basin than in the northern. At La Jara, in township 35 north, the first flow is found at from 56 to 60 feet. Southeast of Alamosa 10 and also 20 miles it is found at 40 feet; at Monte Vista, at 105 feet; at Chritton's, township 39 north, at 158 feet. From the first flow others are met at frequent intervals, sometimes within 5 feet, sometimes not within 50 or more. The deeper flows are generally the stronger. The wells are usually sunk to the second or third; the first is frequently sulphurous. At Monte Vista flows are found at 105, 135, 165. At La Jara, all the way from 60 to 150, the latter being the best. At Chritton's, township 39 north, range 10 east,

flows were found at 158, 166, 223, and 276; that at 166 being about one-fourth as strong as that at 276. The deep well at Alamosa, according to Mr. Bucher, struck "about ten big flows" before reaching that at 932 feet.

The first deep well in the valley was sunk by C. Bucher, of Alamosa, in the summer of 1889. It reaches a depth of nearly 1,000 feet. The cost was $2,750. The writer saw the well shortly after it was completed in 1889. It was then running a fine stream, the full size of the pipe, with considerable pressure. The flow was not increased then, but from data furnished since the flow must be quite 140 gallons per minute, or $2\frac{1}{3}$ gallons per second, an amount sufficient to cover in a year 2,700 acres 1 foot deep with water.

The success of this deep well led the town of Alamosa to sink one. This was bored to a depth of 865 feet, and has a flow, from the data furnished, which must be close to 1,000 gallons per minute.

The success of these deep wells will undoubtedly cause others of similar size to be put down.

The temperatures vary from 46° to 56° in the shallower wells; in the deep ones at Alamosa it is 65° and 75°, respectively This greater temperature makes an additional reason for sinking deep wells, for besides the larger flow, the increased temperature will make the water much more valuable for irrigation.

WATER SUPPLY.

The amount of water supplied to these strata must be enormous. Notwithstanding the multiplication of the wells, and frequently their close proximity, there has been as yet no decrease in discharge noticed from interference with each other. Very few wells are reported as having decreased, and in the cases noted it seems to be from having filled with sand. In Monte Vista, with 80 to 100 wells, Marsh, with his 8 wells, reports an increase. Bonner notes no change.

John Mayers, of Littleton, an experienced well-borer, after visiting the valley, says:

> In one case a man sunk 6 wells, 200 feet apart, the wells being 3 inches in diameter, 400 feet in depth, each well yielding 50,000 gallons of water per day. All 6 wells being sunk so near each other, and not affecting each other, is to me satisfactory proof of the sufficiency of the strata.

The source of the supply has not been investigated. It is quite likely that the disappearance of the mountain streams at the edge of the plain has something to do with the supply, if they do not furnish a large portion of it. Whatever may be the source, the present large number of wells in the valley does not seem to have affected the quantity available in the slightest degree, and the number of wells may probably be doubled or trebled without materially affecting the pressure or flow.

USE IN IRRIGATION.

In the past two years of development the principal object in securing the flowing wells was to have a supply of good water for domestic or stock use, which would render the settler independent of the ditches in the winter season. Some of the waste water was turned around the trees in 1889 and with such good results that it set many to thinking about securing a large flow and attempting irrigation on a larger scale. The success of the deep wells at Alamosa demonstrated that it was feasible. This is the first year of the attempt to use this water there

to any extent, and reliable information can not be had. H. L. J. Warren, the water superintendent of water division No. 3, which comprises all of the San Luis Valley and who officially has to take notice of artesian wells and their uses, speaks of the absolute impossibility of obtaining information asked for without a personal visit to the homes of the farmers. He says:

> Last year (1889) there were no crops raised through the agency of artesian flows other than garden patches. This year there will be not less than 200 farmers in the valley who will crop from 30 to 200 acres and will have no other supply of water except that derived from artesian sources. In my trips over the valley this spring I have been constantly surprised to witness the many ranches that are supplied with wells having a strong flow of water. This artesian moisture I believe will be the means of bringing under cultivation at least 250,000 acres of choice lands in the San Luis Valley that otherwise would remain barren.

INDIVIDUAL WELLS.

S. E. Newcomb, of La Jara, has eight wells of 3-inch bore, which discharge from 60 to 125 gallons per minute each. These wells are sunk from 100 to 170 feet, and cost, with about 40 feet of casing, $40 each. He is irrigating from them this year for the first time.

Thomas Ormond, of La Jara, procures flowing water at 56 feet. The cost was $81. He is irrigating 14 acres without storing.

D. E. Newcomb, of La Jara, says he has seventeen artesian wells on his ranch. They are 3 inches in diameter, cased about 40 feet. Depth 140 to 160 feet. Average flow throws water above casing about 3 inches. Cost $25 each. Temperature 48° F. Have been flowing about two years. Flow constant and about 110 gallons per minute.

In La Jara there are seventeen wells sunk within a radius of 300 feet; the bore $1\frac{1}{4}$ inches; the depth 125 to 185 feet, and yield 15 gallons per minute, at a temperature of $46\frac{1}{2}°$. Four men completed each well in two days. Method used in boring, hydraulic jetting. The cost of each well, $50.

The Empire farm, a few miles southwest of Alamosa, has about forty 3-inch wells, varying in depth from 60 to 120 feet. These wells, the superintendent reports, furnish plenty of water for domestic use, but would not be of any benefit for irrigation purposes for more than an acre of ground. The Excelsior farm also has a large number, 40 to 120 feet deep, otherwise similar to those of the Empire farm.

C. Bucher, of Alamosa, has one of the deep wells. He has three others within 7 miles of Alamosa, 182 feet deep. Water rises 17 inches above the casing, furnishing about 150 gallons per minute.

At Henry, section 36, range 9, Charles Glynn has a 3-inch well, 200 feet deep, yielding $22\frac{1}{2}$ gallons per minute. The cost was $35. The first flow was found at 83 feet.

John Roper, 4 miles north of the above, has a well 90 feet deep, which did flow 12 gallons per minute, since reduced to 8 from not having cased the full depth. He irrrigates nearly 5 acres of trees on his timber claim from it.

The Alamosa town well is one of the two deep wells in the valley, both located at Alamosa. Its total depth is 865 feet. It was sunk from August 10 to September 15, 1889, at a total cost of $1,865. It is 6 inches in diameter for the full depth, with an 8-inch stand-pipe. The flow fills both pipes, and causes the stream to rise in a solid column some 15 inches above the 6-inch pipe, besides the flow from the surrounding 8-inch pipe. The total flow is about 1,000 gallons per minute. This well irrigates the streets of the entire town.

The formation is said to be as follows. It is probable that minor strata of sand are omitted.

	Thickness of strata.	Depth from surface.
	Feet.	*Feet.*
Alluvial soil	3	3
Sand	10	13
Blue clay	511	524
Black sand	2	526
Blue clay	324	856

P. O. Cyle, Liberty post office, has a well 225 feet deep in section 13, township 38, range 9, which was sunk in ten days in 1889 at a cost of less than $150. Flows were struck at 127, 165, and 211 feet. The flow at first was 75 gallons per minute, but the third flow having been shut off by sand, the flow has diminished two-thirds.

C. C. Carrico has a 2-inch well in section 13, township 36, range 10. The total depth is 146 feet. It was begun November 15, 1889, and finished the next day; total cost, $25. Water was struck at 40 feet, 78 feet, and at depths of from 5 to 20 feet further down. Flow, 25 gallons per minute. He has eight others, similar, under his supervision.

Between Alamosa and Monte Vista there are a number of 3-inch wells, Mr. Marsh says, 200 to 300 feet deep, with an irrigating capacity of from 10 to 30 acres each.

At Monte Vista Olando Bonner procures a flow of 15 gallons per minute from a depth of 103 feet; the casing is 2-inch. This well was sunk in December, 1888, in four days, at a total cost of $100. The writer saw the well in January, 1889, and recalls that the water flowed to the second story of the house in quite a stream.

At the same place H. H. Marsh has eight wells from 109 to 135 feet deep, similar in size and discharge to the Bonner well. These were sunk from July to December, 1889, the later ones in a single day. The average cost was $65, but now (June, 1890), Mr. Marsh says, they could be put down for $45.

J. M. Chritton, 12 miles north of Alamosa and about the same east of Monte Vista, has two 3-inch wells within 160 rods of each other, which he says are like as two peas in flow and quality of water. There is only 1 foot difference in depth. Total depth, 277 feet. Pressure sufficient to raise the water 30 feet above the surface. When first struck the water was thrown full size of casing 9 inches above the pipe. It is now 7 inches. This would correspond to a discharge of something like 135 gallons per minute when first struck, and to a present discharge of 120. A small flow was struck at 159 feet, and one of from 30 to 40 gallons per minute at 165. The first well was sunk to this flow in August, 1889, by Mr. Chritton with a machine of his own make, and has since been deepened. This flow was used to irrigate garden and trees with the best of results.

The record of the strata passed through was carefully kept, and is given as illustrating the characteristic formation of the valley:

Strata.	Thickness.	Depth.
	Feet.	*Feet.*
Dark sandy loam	7	7
Coarse sand and gravel	13	20
Fine light yellow sand	22	42
Yellow impervious clay	18	60
Blue clay, or soft slate	98	158
Black sand with flow*	1	159
Blue clay	4	163
Black sand†	3	166
Blue clay	45	211
Fine black sand‡	12	223
Blue clay	53	276
Black sand§		

* Small flow. † Nice flow; about one-quarter what we now have. ‡ Flow.
§ Here we struck such a flow that with our pump we could go no deeper.

NOTE—Strong flow. Water is soft; has both soda and sulphur; very clear; 56°.

At Saguache John Braun has a 3-inch well 185 feet deep, which flows 35 gallons per minute. First flow was struck at 155 feet, second at 175.

T. Ashley, near the same place, has a 4½-inch well 140 feet deep, flow of 50 gallons per minute.

G. Ball's well is 145 feet in depth, 4½-inch casing, flows about 70 gallons per minute.

Chas. I. Moore's well, 5 miles west of Chritton's, is 165 feet deep. The flow is 60 gallons per minute, with a pressure estimated by the owner of 20 pounds per square inch. It irrigates five acres of garden and is used to help out the supply of water derived from the canal besides.

Walter H. Graves, Monte Vista, San Luis Valley:

It is almost impossible to designate any particular locality or well, as there are hundreds of them in the San Luis Valley. Nearly every quarter section has a well, and some of them have several.

There are probably one hundred wells within the limits of the town of Monte Vista. Most of the wells are either 2 or 3 inches in diameter. There are two at Alamosa larger, I think one 8 inches and 10 inches, and they are magnificent wells too.

Some of them flow better than others, as would naturally be supposed. I have seen a 3-inch well that would not fill an ordinary bucket or pail in an hour, and other 2-inch wells that would fill several barrels per minute.

We find as the mountains are approached the wells are not so strong, and within 4 or 5 miles of the foothills water can not be found with any of the machinery that we have in the valley for boring the wells.

The water is very soft and pure, although it has in some cases a strong sulphurous smell. The temperature ranges from 40° to 56°, except in the deep wells, where it ranges much higher. Most of the wells range from 100 feet to 200 feet in depth; some are as deep as 700 feet and 800 feet.

The water strata occur all the way down as far as our boring has gone, the then deeper strata giving the best and strongest flows.

[The Empire Farm Co.; The Empire Land and Canal Co.; The San Luis Land, Canal and Improvement Co; M. B. Colt, General Supt., Frank V. Potter, Resident Eng.]

M. B. Colt, Alamosa:

We have, on what is known as the Empire Farm, about 40 3-inch wells, ranging in depth from 60 to 120 feet. This farm is located on sections 5, 6, 7, 8, 18, 36, 10, and 28, 29, 30, 31, and 32, 37, 10 east, N. M. P. M., in Conejos County, Colo. These wells furnish plenty of water for domestic use, but would not be of any benefit for irrigation purposes for more than an acre of ground. We also have, on what we call the Excelsior Farm, which is located on sections 1, 2, 3, 4, 9, 10, 11, and 15, township 35, range 10; sections 24, 25, 26, 27, 30, 31, 32, 33, 35, township 36, range 10; sec-

tions 19, 21, 20, 28, 27, 29, 30, 31, 32, 33, 34, township 35, range 11 east, N. M. P. M., in Conejos County. The wells of this farm range in depth from 40 to 120 feet, and the flow is about the same as those on the Empire Farm.

The wells are all 3 inches in diameter. I do not think from my observation that any number of these wells would furnish sufficient water to irrigate 160 acres of land. As an instance of what I form my opinion on, I will refer to an attempt made by one Charles Carico, located on section 19, township 36, 10 east, N. M. P. M. He built a reservoir on the highest part of his farm about 250 feet square, and banks of sufficient height to hold 4 feet of water. On the inside of this reservoir he put down four 3-inch wells to a depth of about 120 feet, and these four wells have been running into this reservoir since some time last October, and as yet they have failed to wet the bottom of the reservoir entirely. I account for this from the fact that his reservoir is on high ground, which in this valley is more or less gravelly and very susceptible to seepage, and I think the water seeps out and goes as surface water to the lower portions of his field, and before he will get any water in his reservoir he will have the entire surrounding country to fill up and bring somewhere on a level with the bottom of his reservoir, which in my opinion is an utter impossibility. There have been several attempts of this kind made in our vicinity, and all with the same results. There are, however, two wells near Alamosa, which are down to a depth of 940 feet, which flow sufficient water, I think, to irrigate about 100 acres. These wells are 8 inches in diameter, cased to the bottom, and cost about $1,200 each. They both have been flowing for about eight months, and there does not seem to be any perceptible difference in the flow since they were first opened; also I do not see any perceptible difference in the flow of the small wells over the country. I will not attempt to say how many of these 3-inch wells there are in this valley, but if I were going to make a guess at it, I should say that there were at least 5,000.

Irrigation by artesian wells, in my opinion and in the opinion of a great many people in the valley, who have investigated it, is a failure, except by an expenditure of from $1,000 to $1,500, and then they only get water enough to irrigate from 100 to 150 acres.

Of course the reservoir system can be utilized by cementing the inside of the reservoirs, but this, of course, necessitates a great deal of expense, and the expenditure of cash, which a very few farmers are supplied with.

C. S. Aldrich, Monte Vista:

Artesian wells in the valley are so numerous, and the contractors such a multitude, that it is a hopeless task to attempt to give anything like a list of either. Generally the first artesian vein is reached from 65 to 200 feet, and then there are alternate layers of clay and gravel or sand, and in each sand or gravel layer under each clay bed is formed a separate artesian vein. As a rule, the deeper you go the stronger the flow or pressure and the warmer the water. About 1,000 feet is the lowest depth reached in the valley.

General Ira J. Bloomfield, Monte Vista, Colo.:

About Monte Vista there are from fifty to one hundred artesian wells in this immediate vicinity.

Near La Jara there are quite a number of very fine flowing wells, one especially on D. E. Newcomb's place, from which the workmen insist fish came up. This well is 6 inches in diameter and throws up a fine body of water.

At Parma several fine wells are found.

About Alamosa they have some of the best wells in the valley, being the largest and deepest.

In the country north and northeasterly extending on to Saguache there are a great number of very fine wells.

South of here about 6 miles are quite a number of fine flowing wells.

OTHER SOURCES OF WATER.

Incidentally considerable has been learned in regard to the underground supply of water, other than that of sufficient pressure to form flowing wells. The greater part of the information obtained relates to the settled part of eastern Colorado, which is not within the limits of the district assigned to me. West of the one hundred and third meridian there are few settlers on the plains; consequently the means of procuring information were lacking, and little relating to this section was obtained.

The information obtained, however, leads to the one conclusion that both for Colorado and New Mexico there is an immense amount of undeveloped water within moderate distance of the surface which may be utilized, either by pumping or by bringing to the surface by a channel.

I would also call attention to the fact that there is, so far as I know, no law governing these underground waters. Their extent and the amount which can be used without decreasing the supply is still to be learned. The waters of rivers are granted to the users, and the rights of the first users are protected. A similar law should protect the developers of the underground supply, as the Italian law prescribes in respect to the *fontanelli* in that country.

ANALYSES OF WATER.

The following analyses from various chemists indicate the character of the waters from the basins in Colorado. The Denver wells have only 10 grains of solid matter to the gallon, while those of Greeley and Pueblo have, respectively, 89 and 62 or over. The Denver water has therefore been largely developed for boiler supply. The Denver wells are separated from the others by having sodium carbonate as its principal solid. This is present to the extent of about 8 grains to the gallon, and it is an injurious salt in irrigation, for it constitutes what is known as "black alkali," which is more harmful than the common form. In this quantity, however, it is not likely that injurious effects would be noticed for a number of years, except on land already containing alkali. As it can be neutralized by the application of gypsum or common land plaster, it need not be considered as a great drawback to the use of this water. As far as yet used no harmful effects have been noticed by those using this water. The Greeley water has for its principal constituent bicarbonate and chloride of sodium, while the Pueblo wells have sodium sulphate and magnesium carbonate. Of the two the Greeley water is the most injurious and is reported as killing vegetation. The Pueblo water used in small quantities shows no injurious effects.

Analysis of water from Greeley artesian well.

[University of Michigan.]

Specific gravity, 1.00107 (at 60° Fahr.); reaction alkaline. In one United States gallon, 231 cubic inches.

	Grains.		Grains.
Bicarbonate of sodium	44.4284	Sulphates, slight traces.	
Bicarbonate of magnesium	0.5075		
Bicarbonate of calcium	0.5775	Total solids	89.4401
Chloride of sodium	37.3299	Carbonic-acid gas	11.1057
Ferric oxide	0.2391		
Aluminum oxide	0.0583	Total constituents	100.5458
Silica	6.2994		

Or 29.22 cubic inches at 60° Fahrenheit.

Analysis of artesian wells in Denver, Colo. REGIS CHAUVENET, *chemist.*

	Grains to gallon.	Parts in 100,000.
ANDERSON WELL.		
Solid residue	10.41	17.85
Calcium sulphate	0.87	1.49
Sodium carbonate	8.22	14.09
Sodium sulphate	0.44	0.75
Magnesium chloride	0.10	0.17
Ferrous carbonate	0.03	0.05
Silica	0.69	1.18
	10.35	17.73
Lime (CaO)	0.36	0.62
Magnesia (MgO)	0.04	0.07
Soda (Na_2O)	5.00	8.57
Ferrous oxide (FeO)	0.02	0.03
Sulphuric oxide (SO_3)	0.76	1.30
Silica (SiO_2)	0.69	1.18
Chlorine	0.07	0.12
WINDSOR WELL.		
Upper flow.		
Solid residue	10.03	17.20
Calcium sulphate	0.85	1.46
Sodium carbonate	7.93	13.60
Sodium sulphate	0.44	0.75
Magnesium chloride	0.10	0.17
Ferrous carbonate	0.03	0.05
Silica	0.61	1.05
	9.96	17.08
Lime (CaO)	0.35	0.60
Magnesia (MgO)	0.04	0.07
Soda (Na_2O)	4.83	8.28
Ferrous oxide (FeO)	0.02	0.03
Sulphuric oxide (SO_3)	0.76	1.30
Silica (SiO_2)	0.61	1.05
Chlorine (Cl)	0.07	0.12
Lower flow.		
Solid residue	10.76	18.45
Calcium sulphate	0.92	1.58
Sodium carbonate	8.48	14.54
Sodium sulphate	0.44	0.75
Magnesium chloride	0.07	0.12
Ferrous carbonate	0.03	0.05
Silica	0.76	1.30
	10.70	18.34
Lime (CaO)	0.38	0.65
Magnesia (MgO)	0.03	0.03
Soda (Na_2O)	5.15	8.83
Ferrous oxide (FeO)	0.02	0.03
Sulphuric oxide (SO_3)	0.79	1.35
Silica (SiO_2)	0.76	1.30
Chlorine (Cl)	0.05	0.08
COURT HOUSE WELL.		
Solid residue	33.01	56.60
Calcium sulphate	0.36	0.62
Calcium carbonate	1.64	2.81
Sodium carbonate	15.83	27.14
Sodium chloride	14.04	24.07
Magnesium carbonate	0.32	0.55
Ferrous carbonate	0.06	0.10
Silica	0.63	1.08
	32.88	56.37
Lime (CaO)	1.07	1.84
Magnesia (MgO)	0.15	0.26
Soda (Na_2O)	16.71	28.65
Ferrous oxide (FeO)	0.04	0.07
Sulphuric oxide (SO_3)	0.21	0.36
Silica (SiO_2)	0.63	1.08
Chlorine (Cl)	8.52	14.61

CHEMICAL TESTS.

[From H. B. Hodges, chemist and engineer.]

No. 2217.

Sample of water: (artesian well at Riverside Cemetery) received December 3, 1889, from Denver, Colo.

Depth of flow, 550 feet; flow at surface, about 1 gallon per minute.

One gallon contains in solution: Total solids, 11.0 grains. Consisting almost wholly of sodic carbonate.

No. 2293.

Sample of water (D. L. & G. artesian well) received January 2, 1890 from West Denver, Colo.

Sample taken 280 feet from surface. Water does not flow at surface.

One gallon contains in solution: Total solids, 14.25 grains. Consisting principally of carbonate of soda.

Carbonate of lime, 2.1 grains.

Carbonate of magnesia, trace.

Absence of gypsum and Epsom salt.

Excessive amount of clayey matter in suspension.

No. 2229.

Sample of water (K. P. well, from water-bearing rock, 590-640 feet below surface). Received December 4, 1889, from Denver, Colo.

One gallon contains in solution: Total solids, 14.0 grains; suspended matter excessive (clayey).

No. 2216.

Sample of water. (Artesian well at Grant smelter). Received December 3, 1889, from Denver, Colo.

Sample is mixed; 400 feet and 640 feet flows. Well does not flow at surface.

One gallon contains in solution: Total solids 11.7 grains, consisting almost wholly of sodic carbonate.

No. 2215.

Sample of water. (Artesian flowing well 655 feet deep). Received December 3, 1889, from Denver, Colo. (Globe smelter).

One gallon contains in solution: Total solids 11.2 grains, consisting almost wholly of sodic carbonate.

No. 1595.

Sample of water received January 17, 1889, from East Denver, Colo.

Well supplying East Denver shops.

One gallon contains—	Grains.
Carbonate of lime	11.47
Carbonate of magnesia	1.48
Silica	1.31
Sulphate of magnesia	2.52
Sulphate of lime	2.67
Chloride of magnesia	0.46
Free silica	0.20
Sulphate of soda	4.31
Chloride of sodium	4.62
Total solids	29.04
Free ammonia	0.0066 parts per 100,000 parts
Albumenized ammonia	0.0100 parts per 100,000 parts

[Tests by D. O'Brine, chemist Colorado Agricultural College.]

Andrew's well, 200 feet deep, 3 miles west from Fort Collins, Colo.

[932.2 grains to gallon.]

Moisture, 100 C	per cent	15.35
Iron and alumina		Traces
Calcium (Coa)	per cent	3.42
Magnesia (MgO)	do	14.12
Carbonic acid (Co_2)	do	26.20
Sulphuric acid (H_2SO_4)	do	33.25
Chlorine (Cl)	do	1.46
Soda (Na_2O)	do	6.21
		100.01

Lamar, Colo., John Hess, owner.

Total solids	grains to gallon	737
Hardness (total)	grains to L	15
Per. "	do	5.8
Temp. "	do	9.2
Free ammonia	do	.00064
Albumenized ammonia	do	.00164
Chlorine	do	84

Examination of solids of Lamar water.

[Moisture at 100 C, 6.4.]

	Per cent.
Iron and alumina	.74
Calcium (CaO)	7.77
Magnesia (MgO)	6.78
Carbonic acid	9.43
Sulphuric acid (H_2SO_4)	43.10
Alkalies (Noa)	20.39
Chlorine (Cl)	11.82
	100.04

ANALYSIS OF WATERS FROM SUB-DISTRICT IV.

[Colorado Coal and Iron Company, Bessemer, Pueblo, July 2, 1884. Temperature, 80.5 F.]

Result of analysis.

[H. L. Wells, chemist.]

	Parts in 100,000.
Potash	2. 06
Soda	34. 03
Lime	15. 09
Magnesia	9. 91
Iron oxide (Feo)	1. 31
Chlorine	3. 51
Sulphuric acid	59. 47
Carbonic acid	Slight excess
Silica	. 98
Boracic acid	Trace
Lithia	Trace
Flurine	Trace
Phosphoric acid	None
Bromine	None
Iodine	None

	Parts in 100,000.
Manganese	None
Potassium chloride	3. 26
Sodium chloride	3. 26
Lithium chloride	Trace
Sodium sulphate	73. 98
Sodium borate	Trace
Calcium sulphate	30. 24
Calcium carbonate	4. 71
Calcium Flouride	Trace
Magnesium carbonate	20. 81
Ferrous carbonate	2. 10
Silica	. 98
Total solids	139. 34

The water contains a small amount of free carbonic acid, or more probably bicarbonates.

Fariss well, Pueblo.

[Von Schultz & Low, of Pueblo.]

	Grains to gallon.	Parts in 100, 000.
Solid residue	62. 34	106. 80
Sodium chloride	2. 42	4. 15
Sodium sulphate	41. 92	71. 82
Calcium sulphate	3. 43	5. 88
Calcium carbonate	6. 28	10. 76
Magnesium carbonate	6. 16	10. 56
Ferrous carbonate	0. 91	1. 56
Silica	0. 91	1. 56
	62. 03	106. 29

This analysis was made on the filtered water. There was some suspended matter, but as a portion at least came from the bottle in which the water was brought to us the amount was not determined. The gallon referred to is the United States gallon of 231 cubic inches. There were no traces of poisonous metals.

Pueblo well, C. H. Small, owner.

[Test by D. O'Brine, chemist.]

Iron and alumina	Traces
Magnesia	Traces
Calcium	1. 80
Soda	47. 92
Sulphuric acid	11. 82
Chlorine	6. 00
Carbonic acid	32. 43
	99. 97

Found 142 grains to gallon of solid matter.

[*Analysis of water from a surface well at Pueblo.*]

[Test by D. O'Brine, chemist.]

120 feet deep; total solids 862.2 grains to gallon: Moisture 100 C., 4.73.

	Per cent.
Iron and alumina	.20
Calcium (CAO)	.48
Magnesia (MGO)	.38
Soda (Nao)	45.98
Sulphuric Acid (So_3)	.32
Carbonic Acid (Co_2)	16.40
Chloride (Ci)	36.32
	100.08

Cañon City well, Colorado.

[Test by Prof. W. P. Headden, University, Denver.]

I had but a little over 500 cubic centimeters (505); this quantity yielded 0.8945 grains residue, which gave me the following result:

Specific gravity of water, 1.0017; total solids (dried at 100°) contained in 1,000 parts 1.7713.

Sodic chloride	.0208
Sodic sulphate	.4006
Potassic sulphate	.0144
Magnesic sulphate	.1427
Magnesic carbonate	,1000
Calcic	.0050
Ferric oxide	.0027
Silicic acid	.0016
Moisture not expelled by 100°	.0033
	.8945

SPRINGS.

The most important ones reported in the San Luis Valley.

The Los Ojos Calientes, so-called because of their steaming in cold weather, are a group of large springs located in section 18, township 35, range 11, on the west side of the Rio Grande River, owned by Mrs. Florence McIntire and A. W. McIntire, of La Jara, Colo.

The following statement is due to Mr. McIntire:

Some are of immense size, the largest one carrying, according to the Hayden measurement, it is said, 21 cubic feet per second. The temperature is about 60°, and neither that nor the flow varies from winter to summer. The springs rise in lava.

These springs vary in size from the one mentioned to one flowing scarcely 20 gallons per minute. One of the intermediate ones irrigates 10 acres, after losing two-thirds of its quantity on the way.

Another part of the group of springs is below average water line in the Conejos River, and when that branch of the river last summer went dry, just above, we irrigated 100 or more acres by damming just below springs. With one exception these springs all come out at the edge of the lava hills that exist in the south end of the San Luis Valley, and occupy most all the territory between these springs and the New Mexico line and further south. The springs are about equidistant from the mountain ranges on the east and west.

Practically the springs rise between two points of lava hills running further north, and making almost a semi-circle, around which the springs are scattered, the two points being 2½ miles apart. To the east one of the points, along the base of the same lava hill, facing north, two or three springs come out of moderate size, on the land of Miss Francesca Atkinson, and of S. H. Ball, esq. Hon. Gordon Land, who used to live here, stated to me that the temperature of some of the springs was as high as 74°.

The spring which does not come out at the edge of the lava is about three-quarters of a mile north of the main spring.

About 1 mile south of the main spring a hole has been bored through the lava, and at less than 100 feet a small flow of pure water is obtained. This is on the south side of the ridge that runs out northwest.

Ending in the west one of the points mentioned, and not within the line of the solid lava, on the bottom land about 1 mile north of this west point, I put down a 2-inch artesian well; went through a blue clay, exactly like the blue clay present in almost every one of the springs, obtained a small flow at 46 feet, but my tenant objecting to the "rotten" taste, I drove about 15 feet further, and the result was about all the water the pipe could let through, clear water with slight "rotten egg" flavor. It has been running over a year without diminution. Piped to the water.

Abstracts of springs reports.

Name.	Locality.	Remarks.
E. C. Tolle, Pueblo, Colo	Sec. 15, T. 18, R. 63	Would run one barrel per minute. Boils out of pure white sandstone. No rock above or below the spring.
Do	Sec. 23, T. 18, R. 63	Do.
C. C. Flem, Pueblo, Colo	Sec. 3, T. 20, R. 64	This spring has a small flow; constant; not affected by seasons. Good drinking and cool.
Fred Rohrer, Pueblo, Colo	Sec. 32–33, T. 20, R. 62.	Fleming Spring has large flow; constant; good water. Owned by J. W. Caulfield, Pueblo, Colo.
E. C. Tolle, Pueblo, Colo	Sec. 15, T. 18, R. 63	Will run one barrel water per minute. Boils up out of pure white sandstone. Owned by J. V. Holland, Pueblo, Colo.
William G. Finley, Crow, Pueblo, Colo.	T. 24, R. 66	Owned by Mr. Boyton, Pueblo, Colo. Salt Creek post office. Springs rise in creek bed from several directions, with water enough to irrigate 200 acres.
Do	Sec. 10, T. 24, R. 66	Owned by William G. Finley.
Do	T. 25, R. 66	Owned by Jesse Marshall, Rye, Pueblo County, Colo.
Do	Sec. 22, T. 24, R. 66	Owned by Mr. Duckworth, Crow, Colo.
Frank Person, Greenhorn, Colo.	Sec. 24, T. 24, R. 67	Person Spring is large; not affected by seasons. Water hard; rather warm in winter, cold in summer. Comes from limestone.
E. M. Beckwith, Rye, Colo	Sec. 27, T. 24, R. 67	Beckwith Spring is large; constant in flow; unaffected by seasons. Water hard; cold in summer, warm in winter.
Hayden & Dickerson, Denver, Colo.	Sec. 24, T. 24, R. 67	Do.
J. M. Duckworth, Crow post office, Pueblo, Colo.	Sec. 21, T. 24, R. 66	Do.
William Meredith, Rye, Colo	Sec. 36, T. 24, R. 68	This spring, "State Spring," is the largest of several large springs. Would irrigate about 40 acres.
George A. Watson, Lamar, Prowers County, Colo.		Number of springs in the vicinity of Butte Creek, fed by springs of subterranean waters. The deeper wells are dug the higher the water rises. Water obtained from 20 to 75 feet. A well drilled at Wild 230 feet; water raised 45 feet. At Albany well is 290 feet; water raised 200 feet.
C. B. Bowman, Walsenburgh		A spring 3 miles northwest of Walsenburgh flows 3 cubic feet per second; sulphur; 73° Fahr. M. J. Coots, owner. The only large spring in Huerfano County.
George T. Herbert, Lamar, Colo.		This well is 235 feet deep. Water is struck below sandstone and shale, rising 20 feet. Large supply.
Willow Springs, 15 miles south by southwest of Lamar.		Flow, medium and constant; slightly affected by change of seasons. Water is good, slightly alkaline, coming from sandstone.
D. Zimmerman, Lamar, Colo	Sec. 4, T. 35, S. R. 41 W.	Willow Spring has a large flow; constant; not affected by seasons. The character of the water is good; comes from yellow sandstone.
Iron Springs, Robert C. Wilson, Beulah, Colo.	Sec. 22, T. 22, R. 67	Supply is small, but affected by seasons. Strongly impregnated with iron, coming from a sandstone formation. Water warm.
Red Creek Spring, Thomas J. Livesey, Pueblo, Colo.	Sec. 5, T. 22, R. 68	Flow, small; constant; unaffected by seasons. Contains iron, soda, sulphur, magnesia. Analyzed by Professor Lowe, of Lieutenant Wheeler's Survey. Used by the public. Not improved.
Mulvane Springs, D. Zimmerman, Lamar, Colo.	Sec. 29, T. 27, S. R. 47 W.	Two springs; flow, about 100 gallons per minute; constant; not affected by seasons. Water is cold. No rock visible.
George T. Herbert, Lamar, Colo.		Artesian well 11 miles southwest of Lamar, and 80 feet above has depth of 150 feet. Water raised immediately within 41 feet of top. Stands steady at this depth.

[Form of contract for boring well.]

WELL-SINKING CONTRACT.

This agreement made this 10th day of October, A. D. 1889, between the Union Pacific Railway Company, of the first part, and Comstock Brothers, of Arapahoe County, Colo., of the second part, witnesseth that said party of the first part proposes sinking a well in the vicinity of the Kansas Pacific shops, in Denver, Colo., to a depth not to exceed 700 feet, and that said party of the second part for a consideration hereafter mentioned, bargains and agrees to do all digging, drilling, boring, casing, or other work connected therewith, or rendered necessary by the sinking, casing, completing, and turning over in a complete and accepted condition the aforesaid well to the party of the first part.

It is understood and agreed that the work on said well shall commence at such time as the party of the first part, by its supervisor or engineer, shall direct, and not more than five days from the date of this contract, and that such work shall proceed with reasonable diligence and speed until said well is completed, or until it reaches the aforesaid depth of 700 feet, or unless the party of the first part shall otherwise elect.

If the party of the second part shall fail to prosecute the work with proper dispatch, the said party of the first part may, upon giving three days' notice to the said second party, declare this contract forfeited and abandoned, which declaration shall absolve said first party from all obligations under or in any wise growing out of this agreement.

Work under this contract shall be completed by the —— day of ———, 1889, and no compensation shall be made to said party of the second part for hindrance or delays arising from any cause; but if such hindrance or delays arise from any cause other than the fault of the party of the second part, then said party of the second part shall be entitled to such extension of time for the completion of this contract as the supervisor or engineer in charge of the work shall determine.

No part of the work under this contract shall be sublet or transferred without written consent of the party of the first, and no such written consent shall release party of the second part from any obligation.

The party of the first part reserves the right to suspend or terminate the work embraced in this contract for reasons not herein specified, and party of the second part agrees to discontinue all work at once after having received notice of such suspension or termination, in which case party of the second part shall be entitled to payment in full for all work actually done, but shall make no claim for consequential damages or anticipated profits, or damages of any kind, resulting from such suspension or termination.

It is understood that there shall be but one class of work considered in this contract, and that this work shall consist of sinking a hole of a suitable size to such depth, not over 700 feet, as aforesaid supervisor or engineer may direct, and the placing to the satisfaction of said supervisor or engineer in charge of the casing of the well (casing to be furnished by the party of the first part), and for this work as a whole complete payment will be paid.

In consideration of the faithful performance of said work and of all the conditions of this agreement and the specifications herein contained, said first party agrees to pay second party as follows: For well, completed and cased, of proper form and workmanship, and accepted as complete and satisfactory by party of the first part, ——— per foot of depth, measuring from the natural surface of the ground at a point where the well is sunk.

An estimate shall be made when the entire work shall have been completed and accepted by the party of the first part as complete; when this shall have been done, and when the party of the second part shall have executed to the said party of the first part a release and receipt in full of all claims and demands whatsoever growing out of this contract or performance of work under the same, then payment in full in accordance with the above-mentioned prices shall be made.

In testimony whereof the said parties have hereunto set their hands the day and year first above written in duplicate.

THE UNION PACIFIC RAILWAY COMPANY.
By ——— ———.
By ——— ———.

REPORT ON NEW MEXICO, BY DIVISION FIELD AGENT L. G. CARPENTER.

So little information is to be obtained from New Mexico, and the means of rapid communication are so small, that sufficient information is not at hand to divide New Mexico into clearly defined districts, by which any of them can be demonstrated as artesian in character. For present purposes New Mexico is divided into three districts, one including the Rio Grande Valley; the second the Pecos Valley, which extends nearly the whole length of the eastern part of the State; and the third district to include the northeastern portion of the State, which is not drained by the Pecos.

The characteristics of New Mexico are in some respects like those of Colorado. There are few living streams. The water supply is scant. Passing away from either the Rio Grande or the Pecos Rivers there are stretches of ground in which no water can be found. Springs are scarce in a great portion of the region, even in the mountains, and when present the streams rarely extend for more than a short distance from their source. The Pecos Valley, however, is supplied with some remarkable springs, some of which are probably among the largest of the world. Near Roswell one is reported that supplies a stream 50 feet broad and 3 feet deep. Several other springs in the same vicinity are second only to it in size. There are many interesting basins in New Mexico which would undoubtedly repay investigation. It was impossible with the time at my disposal to visit any region off the railroad. As there was but one running from north to south, the portion hastily passed through bears a very small proportion to the whole area. Some of the most promising areas were 200 miles from any railroad. Population is sparse, and consequently the means of obtaining information are wanting. In many cases but one or two letters could be exchanged, and it was therefore difficult to learn of those who possessed information and secure a reply before it was too late to be of use. These conditions have made it impossible to secure a report that should do anything like justice to New Mexico and her resources of water.

ARTESIAN WELLS.

So far but few attempts to sink artesian wells in New Mexico have been made. A few deep borings have been made, but nearly all have been for prospect holes. Only five deep borings have been made, and these were at Fort Wingate, Deming, Raton, Las Vegas, and Santa Fé. Several holes were sunk in southeastern New Mexico to depths of 200 or 300 feet by the Southern New Mexico Railroad Company.*

* Since this report was completed a successful artesian bore has been completed about 320 feet deep, with water flowing at moderate pressure above the surface. Location: six miles S. by E. of Springer.

THE RIO GRANDE.

Santa Fé, in the northern part of the Santa Fé Valley, was visited, with Colonel Nettleton and Professor Hay. At this point an artesian well had been attempted, 9 miles south and west of Sante Fé, near a body of very fine land, which it was hoped to water. At 360 feet water was struck which rose to within 70 feet of the surface. This seemed a good supply of water as far as tested. Thirty-one barrels were taken out in 21 minutes without reducing the height. Granite was struck at 96 feet, and the boring was continued for 155 feet in it. It is possible that a location lower in the valley might have secured a flowing well.

Several wells have been tried in the sandy feeders of the Rio Hondo, south of Santa Fé; some with success.

Mr. Fisher's well, 3 miles south of Santa Fé, is 40 feet deep. Water rose 24 feet in the well. Large supply.

At Santa Fé, a man named Pedro has a well 28 feet deep, 6 feet in diameter, near the Atchison, Topeka and Santa Fé depot. The water was 8 feet in depth—it has been 16. By means of a windmill enough water is raised to irrigate three acres, mostly in garden crops. The quantity is so great that, in attempting to sink it deeper, three men could not keep down the water sufficiently to allow the work to progress.

Near San Pedro, 40 miles south of Santa Fé, several wells have been sunk which were not flowing, but are artesian. In two of these, shafts were sunk to about 90 feet, then a drill-hole was bored 300 feet further in one, 400 in the other. The water rises from 20 to 40 feet in the shaft, and is in such quantity that one of them furnishes water for three boilers, two water-jacket furnaces, and a 25-stamp mill.

After leaving Santa Fé we enter the fertile bottom lands of the Rio Grande. It was reported that there was an artesian well at Albuquerque. A personal visit showed that no special attempt had been made, and that the wells which gave rise to the report were not flowing wells. The city water works has two wells, 20 and 22 feet in depth, respectively, and 25 and 33 feet in diameter.

In 1889 a $1\frac{1}{4}$-inch pipe was driven in the bottom of the well some 38 feet deeper. This flowed some 14 to 16 gallons per minute into the shaft. Both wells are now supplied in this manner. Last year some 650,000 gallons per day were pumped. Water is struck in the valley at from 6 to 8 feet. Usually that of the third stratum, at 30 feet, is used. It rises to within 4 feet of the surface. The amount of water underlying these bottom lands is certainly great. The supply may be furnished by the Rio Grande and its tributaries. Nearly all the cañons in the neighboring Sandia Mountains have running streams which do not reach the Rio Grande. As soon as they reach the sands they disappear.

There are a number of springs, especially on the east of the Rio Grande, in this region. All are small. Their flow does not seem to be enough to account for the amount of water that must come from the Sandia Mountains. Among these are the Hubbell Springs, township 8 north, range 3 east, 5 miles east of Isleta, which furnish a large amount of stock water and are not affected by the season.

Cabra Spring, in township 8 north, range 3 east, 15 miles south of Albuquerque, is about the same size as Hubbell Springs, and flow is of the same character. Both are about 5 miles from the mountains.

To the southeast, in Coyote Cañon. are mineral springs used for bathing.

Half way up the mountains are fresh-water springs. In general these springs are used for stock only.

Along the Rio Grande, between San Marcial and Rincon, stretches a remarkable plain, to which the Spaniards gave the name of the Jornada del Muerto, or the Journey of Death. It is some 70 miles from San Marcial to Rincon. In the whole distance of the plain, which the road has to take because of the impassable cañon of the Rio Grande, there is not a living stream.

Dr. Bowman says that in an area of 100 by 25 miles, in times past or present, outside of the railroad stations, there have been but two human habitations, one at Martin's well and one at a small spring which soon sinks into the sand. The plain, containing some 2,000,000 acres, has a fine crop of gramma grass, and is fertile if water were supplied it. There is but one spring, and that a small flow, on these plains. The mountains on the east and west have but few, and, as mentioned of the region near Albuquerque, these flows are not sufficient to account for the water which there is every reason to suppose must flow from these mountains. The Martin well was sunk many years ago. It is reported to be 160 feet deep and to supply an abundance of water. There is an attempt now being made to find artesian water on the Jornada. The following is an interesting statement from the San Marcial Reporter, of January 4, 1890:

Several enterprises are under way to reclaim this extensive and valuable tract by bringing on to it the surplus waters of the Rio Grande, and there are those who believe that water sufficient for irrigation purposes could be brought to the surface by means of artesian wells. Mr. W. L. Holmes, of this city, has already commenced an experiment of this kind on the east side of the Jornada. What strengthens the belief that it is possible to strike an underground current having a source sufficiently high to force the water to the surface are three springs now flowing about 16 miles east of Lava Station, the principal one being known as Ojo Annayá, and the large number of mounds evidently raised by the deposits of springs now extinct. That these mounds were so formed is shown by the pipes to be found in their centers, and the fact that they are composed of sulphate of lime, the material which strongly impregnates the springs now in active operation. The theory advanced to account for the extinction of these springs is, that when the deposit by precipitation and the soil, aided by the wind, became so high that the water ceased to overflow the incrustation at the mouth gradually closed the orifice and the water sought other outlets.

There are not less than one hundred of these mounds scattered along the east side of the Jornada, some of them 100 feet in diameter at the base, and rising from 5 to 30 feet. The water from the flowing springs is so strongly impregnated with hydrosulphate of lime as to render it almost unfit for human beings, but it does well for stock and vegetation.

From the lower end of the Jornada at Fort Selden the Rio Grande again broadens out into a beautiful valley. It is a basin in shape. Both to the east and west are the mountains, which close in at Fort Selden on the north, and at El Paso on the south. The length is about 40 miles. The Organ Mountains, 12 miles from the river, form the eastern rim of the basin. It would require a further examination to show if the other conditions of an artesian basin are present.

No deep wells have been attempted. The deepest reported is 65 feet, but from these wells of moderate depth water rises nearly to the surface. The following letter from Mr. John De Meir, a citizen of Las Cruces, shows the experience at that point.

I am convinced that our valley is one immense artesian belt and will cite a few cases to confirm it.

The deepest drive well here is 65 feet, at Col. Albert Fountain's. The water stands at 4 feet of the surface. Major Llewellyn's well, 700 feet distant and south of Fountain's, is driven 45 feet; water stands at 4 feet. One mile south of his well, McClure Brothers drove down 65 feet; water stood at 4 feet. They broke their pipe and could drive no further. An open well up on the foothills, upper part of town, sunk to a depth of 45 feet, and the bottom being about 12 feet below the valley land, gave a poor supply of water. Mr. Ackenback, the owner, drove a pipe 16 feet in the bottom

and it rises in the well and yields all the water they desire. So far the strata here is the same as in California. In driving wells every few feet they strike a hardpan that makes it slow, hard work until it is penetrated, and when passed through it will drive easily till next hardpan is struck. These stratas are from 2 to 4 feet thick, and in sinking open wells it is necessary to use explosives. I have been hammering at the people for the past year to raise funds and give it a trial, and while all are of the same opinion as I am, it is slow work to get them to move in the matter. On the east we are surrounded by a high mountain range 2,500 feet higher than the valley, while on the west we have a high mesa and mountains. At Fort Selden the mountains meet and form a narrow pass worn through the rock, and at El Paso they meet again and form another pass, so that we are truly a basin with a rock pass above and below us. I send a diagram, which may give a better idea of our situation.

Mr. De Mier, of Las Cruces, says:

About 28 miles above here, in upper end of this valley or above it proper, springs crop out at river bank and keep the lagoons full when Rio Grande is dry. Am informed same feature prevails this side of El Paso, Tex., at lower end of the valley. There are immense bodies of water flowing from hidden veins in the Organ Mountains 12 miles east of this point; one in particular is over 50,000 gallons an hour. At the Memphis mine that amount was pumped day and night for over a year. It came in at about 130 feet in the shaft, and only part of it entered the shaft. Mine has been closed down for past six years on account of water. There are a number of springs on both sides of the range, mostly on west side, draining into this Mesilla Valley.

W. J. Joblin, the manager of the mine above referred to, reports substantially the same, except that he put the inflow at 20,000 gallons per hour.

J. H. Riley, 12 miles northeast of Las Cruces, has a well 126 feet deep, in which he gets water at 92 feet. He is lower than the Memphis mine, and the water he strikes is soft, while that at the Memphis mine is hard. There is a spring at this same ranch flowing about a cubic foot per minute.

Surg. A. P. Frick, Fort Selden, at the upper end of the valley, says:

I have had no opportunity to gain any knowledge of springs or water supply in New Mexico beyond the immediate vicinity of this post. On the left bank of the Rio Grande River, one and a half miles above the location of the post, there is a hot mineral spring, the head of which, so far as yet developed, is about as high as high-water mark of the river. It does not appear to be affected by the rise or fall of the river. When the bed of the river is dry (as was the case from about August, 1889, to February, 1890), several feet of fall from the head of the spring to the bed of the river shows a flow equal to about one inch of water in a pipe under a pressure of say 6 inches of head. During low water in the river, or a dry bed, this water flows from excavations that have been made into a rocky bluff that juts into the river bed. The temperature of the water is 150° F., and a quantitative analysis shows 205 grains of solids to the gallon. No qualitative analysis has been made.

The water supply of this military post is now derived from a drive well, 600 yards from the post, about half way from the foot of the mesa on which the post is situated and the bank of the river. Between the Mesa and Mount Roblero, on the other side of the river, the valley narrows down to about 1,200 yards. At a depth of 10 feet a quicksand is found, which bears a good clear potable water. The drive well point above referred to is at a depth of 24 feet below the general surface of the river bottom or valley, and the pump used yields a flow of about 30 gallons per minute. It has been used about nine months, and has never shown any abatement in the flow, as far as tested. The water is excellent in quality, and holds in solution only $17\frac{1}{2}$ grains of solids to the gallon.

The following is in regard to this same valley:

A new comer into this part of the valley (Ferdinand Horaquelle d'Amians) purchased from William Dessauer, of Las Cruces, about 500 acres of land at Brunswick. He is now engaged in sinking a point for water; is down 72 feet. Each blow with the hammer drives water out at the top of the pipe, so it can be plainly seen that this is but little less than a flowing well. At present he is in bad water and intends to go down 28 feet more, unless he shall get good flowing water before reaching the depth of 100 feet.

In the dugwells at Las Cruces, which reach water at 18 feet, the same phenomena of a moving current is noticed as is observed in the valleys of the Platte and the Arkansas Rivers. This movement, according to the measurements of Dr. Petin, of Las Cruces, is one yard in five minutes.

C. V. Mead, of Victoria, a few miles south of Las Cruces:

In from 6 inches to 12 feet we reach the plain of water underlying the Rio Grande Valley, the bottom land along the river. This plain rises and falls with the rise and fall of the river. About a mile from this place, section 22, township 25 south, range 2 east, water seeps out at the foot of the mesa a trifle above the valley water, apparently giving reason for the belief that the water underlying the plains westward toward Deming is independent of and more elevated than that of the valley.

At Deming, some 40 miles west of the Rio Grande, the first deep well sunk for water was put down in 1884.

In sinking 980 feet, thirteen strata, bearing water from 70 feet downward, were passed through, but none of sufficient pressure to bring the water to the surface. The several strata below 770 feet brought the water nearly to the surface. From 773 it rose to 28 feet of the surface; to 21 from 836; to 19 from 886; to 9 feet from 912. After standing a year at 9 feet 3 inches from the surface, the water settled back to 16 feet 3 inches.

East of the Rio Grande and between the Organ and the San Andreas Mountains on the west and the Guadalupe and the Sacramento on the east is an extensive valley covering several thousand square miles. There are few if any people living in this vast area. In the north are gypsum beds covering, says Colonel Fountain, of Las Cruces, over 1,000 square miles. Water is found close to the surface. In driving across these gypsum beds places are passed which have a distinctly hollow sound. In 1862, when passing over these beds, he came across a hole in the bottom of which there was a rapid stream.

There are very few springs in this valley. Of one Mr. C. V. Mead, of Victoria, says:

The Ojo de los Alamos, given on the Department of the Interior map near the Texas line, about 70 miles east of El Paso, is well up on a little mountain, which is lower formation forced up through the upper formation, and gives every appearance of artesian water, which has followed the stratification, in which it flows, in the upheaval. The plateau bounded on the north by the Sacramento Mountains, on the east by the Guadalupe Mountains, on the south by the Sierra Blanca, and the west edge of which is the Hueco Mountains, gives every appearance of being an artesian country.

In the extreme northern part of this valley the Southern New Mexico Well Boring Company attempted to bore some wells, but their outfit not being adapted to rock, most were abandoned at moderate depths.

Major Llewellyn, of Las Cruces, president of the company, stated that the first well was about 25 miles from White Oaks, which is in township 6 south, range 13 east, at the head of the Malpais or ancient lava beds. This was abandoned at 280 feet.

At the northwest end of the Sacramento Mountains, at a depth of 90 feet, water was found, which rose to 30 feet of the surface. There several successful pumping wells were put down for B. E. Davis, of San Augustine.

The Pecos Valley has, until recently, been yielded to the cattle companies. Now a good many settlers are entering the lower portion of the valley.

The headwaters of this river are in the mountains near Las Vegas and Santa Fé; thence its general course is southeasterly and southerly,

Above Roswell, 100 miles from the southern border of the Territory, the river is subject to droughts and sometimes runs dry. At that point it is replenished by the waters of some of the largest springs in the world, and from that place the stream has never been known to be dry.

NATURAL SPRINGS.

These springs are remarkable for their size. The following are the summaries of some reports by different persons:

Name.	Remarks.
J. C. Lea, Roswell, N. Mex.	Head of North Spring River, Sec. 36, T. 10 S., R. 23 E. Largest spring in the world. Makes a rapid river 50 feet wide, 3 feet deep. Constant, not affected by seasons; clear; rather hard. Temperature, 45° to 50°.
Patrick F. Garrett, Roswell, N. Mex.	North Spring River, same as above. Large; constant; not affected by seasons. Water is limestone. About 60° the year round. Owned by Capt. J. C. Lea.
J. A. Ermin, Roswell, Lincoln County, N. Mex.	North Spring River, same as above. A stream 15 to 20 feet wide, 2 feet deep. Owned by L. M. Long, Roswell, N. Mex.
Do	North Berando, in Sec. 17, T. 10 S., R. 24 E. Same description as above.
Do	South Berando, in Sec. 5, T. 10 S., R. 24 E. Same description as above.
L. M. Long	The North and South Spring River springs and the three Berandos, owned by Capt. J. C. Lea, William Robert, Colonel Miller, located in Ts. 10 and 11 S., Rs. 24 and 25 E. Flow is constant; not affected by the seasons; comes from limestone rocks. Temperature 67° in summer; 63° in winter. Total flow, from 700 to 800 cubic feet per second. Water excellent for domestic and irrigation purposes.

NON-SURFACE WELLS.

East of the Pecos there is a number of wells. These extend from Roswell to Eddy, and are about 15 miles apart. Water is found from 12 to 40 feet deep, usually in abundant quantities. One well furnishes water for 10,000 cattle.

In the extreme upper end of the Pecos Valley the Las Vegas Development Company sunk an experimental well 1,860 feet. A vein of water was struck at a depth of 1,300 feet, the water rising to within 50 feet of the surface of the ground At a depth of 1,500 feet the hole was cased.

At a depth of between 1,600 and 1,700 feet, water was again struck, it rose to the surface of the ground and overflowed slightly, but as the seat of the casing got broken the water got between it and the well and escaped, still remaining, however, at a level of 50 feet below the surface of the ground.

This well was about 1½ miles north of Las Vegas. Another hole to a less depth was bored south of Las Vegas.

John Campbell, C. E., of Las Vegas, writes:

> You may have observed at the Hot Springs a break in the strata—lying almost perpendicular—this break lies in a northerly and southerly direction. Three miles south of Las Vegas and to the east of the above-mentioned break or upheaval, a hole was drilled for coal about eight years ago. At a depth of between 325 and 335 feet a bed of quick sand, containing a strong flow of running water, was struck. The water rose to about 50 feet from the surface of the ground, but, as coal was the object in drilling, the work was then abandoned. There was every indication of an inexhaustible supply of water at this place.

In the northeastern corner of the State several wells have been sunk on the Denver, Texas and Fort Worth Road. They strike water at from 100 to 300 feet, which is artesian in character, but is not flowing.

Raton is the only place in this section which has attempted an artesian well.

It was sunk to 1,872 feet by a company of citizens in 1887. It was intended for a town supply, but no flow was struck. After passing through the surface formation this well went through dark, sandy shales to 1,729 feet, then 14 feet of fine, black sand from which hot mineral water rose to within 300 feet of the surface; then 74 feet of shale followed by 61 feet of fine, dark-brown sand which had more of the hot mineral water, rising to about 300 feet of the surface.

J. S. Sheeter says of this well—

I believe for the most part our country can be successfully prospected for artesian water. Our experiment at Raton was a partial failure, not getting a flowing well, but one that would furnish a strong pumping stream. I believe we would have reached a flowing stream had we not gone so close to the mountain. The mouth of the well is located at the very foot of the mountain and upon much higher ground than the body of the town. We have plenty of natural artesian streams around us that are perpetual in their supply, viz, large mountain springs, lakes on top of mesas, etc., which are at much higher elevations than the valleys and lower table-lands.

In addition to the wells before given one was sunk near Fort Wingate by the Cosmopolitan Petroleum Company in 1883. Prof. N. A. Bibikoo, the former geologist of the Atlantic and Pacific Railroad, Albuquerque, N. Mex., reports that at a depth of 75 feet water was obtained, flowing 12,000 gallons per day, and at 106 feet 80,000 gallons per day.

It would seem, from the hurried inspection that could be given and from the meager information obtained, that there are a number of regions in New Mexico where some of the conditions for an artesian flow may exist. To one going through the country for the first time the impression is one of extreme aridity. Few springs, no streams frequently over hundreds and thousands of square miles. The evidence in regard to the great body of underground water, frequently at very moderate depths, therefore, struck one with surprise. Such evidence repeated from place to place had a cumulative effect to a person in such circumstances that it would not have to a person in other surroundings. The development of such supplies in New Mexico has not been begun. The knowledge thus far had is due to accident, not to a systematic development. With a fuller development there is every reason to believe that the quantity of water obtained will surprise even those who know what has so far been found, and that many of the plains which now are truly deserts will be such garden spots and centers of fruit culture as the climate permits.

L. M. Long, of Roswell, says:

I have traveled all through Colorado, New Mexico and part of Arizona, and I have never witnessed anything to equal the spring rivers of this country. They are, in fact, spontaneous rivers. We are better blessed with water than the average Western country, and still we have fully 1,000,000 acres of as fine land as there is in the world, that can never be reclaimed except by the artesian process. I hope by this time next year I may be able to solve the problem, as I am the only one in the country who has an artesian plant. It is also a prospecting machine, as dimension of drill is only 3 inches. I hope our country will be able to command your personal attention, as the field is worthy of it.

From *P. F. Garrett*, Roswell.

As indicated on blanks, I could give you no idea of number and extent of springs, nor the flow of water from them in the space there allotted.

I will first mention artesian wells. Many have been contemplated, and but one has been attempted, that of L. M. Long, the work on which has been suspended on account of accident to machinery.

Take the rivers and springs in rotation as they are important in magnitude.

Rio Pecos.—As you know, this river traverses ranges 25 and 26 east, north of the second correction line, and also south of that line for a distance of about 20 miles when the bends run into range 27 east occasionally, but the principal portion of the river is embraced in range 26 as far south as township 19 south, when it bears east and traverses ranges 26, 27, 28, and near line of Texas, 29 east.

Rio Hondo.—This river is formed by the confluence of Rio Bonito and Rio Ruidoso, in township 11 south, range 18 east, and running east, confines itself to townships 10 and 11, and discharges into the Rio Pecos.

North Spring River.—This stream rises in section 36, township 10 south, of range 23 east, from monstrous springs. Twenty yards from the head this stream is fully 40 feet wide and averages that for a distance of about 4 miles running eastwardly, where it empties into the Rio Hondo, in section 34, township 10, range 24 east. There are two silght falls in the course of this river. It runs smoothly without any rush. The water is limestone with an almost imperceptible tinge of gypsum. It is clear and limpid with a depth of 2 to 4 feet. No watershed and it has never varied (rising or falling) 1 inch within the memory of the oldest citizen. There are no rocks of importance at its head nor along its banks. The volume of water is increased along its route by several valuable springs.

South Spring River.—This river rises in section 22, township 11 south, of range 24 east. The description of North Spring River will apply to South Spring River, except that it is deeper, not so broad, the water runs much swifter, clear, same class of water, no rocks, carries about the same volume, no important rise and fall, is about 5 miles long, runs north of east, and empties into the Rio Hondo in section 9, township 11, range 25, 700 yards from Rio Pecos.

Middle Berando River.—This river rises in section 5, township 10 south, of range 24 east, from springs. It is about one-half the size of North Spring River, runs more rapidly, same class of water, few rocks, very seldom rises, always full supply, forms confluence with the North Berando Spring in section 14, and South Berando River in section 22, township 10, range 24, empties into Rio Hondo in section 25, township 10, range 24.

North Berando Spring.—This spring is in section 11, township 10, range 24. It supplies water to irrigate two good farms and swells the Middle Berando River in section 14. Same class of water. Length of stream about 500 yards.

South Berando River.—Rises in section 17, township 10 south, of range 24 east, from springs. Carries nearly as much water as the North Berando; same class. Description of latter named will describe this. The above three Berandos deposit their waters in Rio Hondo.

Bitter Creek and Springs.—This creek comes from a lake in section 9, township 10 south, of range 25 east. This lake is fed from subterranean sources. The valley abounds in springs, and they feed this creek all along its course. There is another (nameless) creek which runs into the Rio Pecos (a distance of about 400 yards) in section 15. This (Bitter) creek is about 3 miles long and empties into the Rio Pecos in section 28, township 10 south, 25 range east. Water strongly alkali. Sufficient water for half dozen farms—three in operation.

Seven Mile Spring.—This is 7 miles south of mouth of Rio Hondo. A continuation of very free springs, capable of supplying water for three or four farms. It rises in section 13, township 12 south, of range 25 east, and runs into the Rio Pecos in section 20, township 12 south, of range 26 east. Splendid water. No rocks.

Nine Mile Spring.—Nine miles south of mouth of Rio Hondo. Rises in section 31, township 12 south, of range 26. Empties into Rio Pecos in section 33, township 12 south, range 26 east. Fac simile of Seven Mile Spring.

Rio Feliz.—This stream empties into the Rio Pecos in section 35, township 13, range 26. It rises in the mountains more than 50 miles west of the Pecos, runs a fine stream of water for 4 or 5 miles, sinks, and rises again a considerable stream within 3 or 4 miles of the Pecos. Fine waters, 25 feet broad (in pools), 3 miles from Pecos. Subject to sudden freshets from its head.

Rio Penasco.—Rises in mountains 68 miles west of the Rio Pecos, runs 8 miles, sinks, rises again in section 18, township 18 south, of range 26 east. Plenty of water at head; size and class of South Spring River. However, acequias have been taken out at the sinks, and it is said that cattle have trodden it down so that water runs some 30 miles in old bed. The land is being rapidly located.

I have taken you down the Rio Pecos some 50 miles and have left out many springs and living lakes. I could go on to Seven Rivers, Rocky Arroyo, Black River, Delaware River, Grape Springs, and various minor streams, springs, and lakes. The water sinks in several of them, but often rises again. One branch of Seven Rivers runs under a mountain and disappears. The banks of the Rio Pecos are studded with excellent springs. One spring (although on both sides the Pecos) yields more water than the supply of the city of Denver. This, according to the resident engineer of the Pecos Irrigation and Investment Company, who is a resident of Denver. I would

like to show you, or any one, if interested, the water facilities of the Pecos Valley. Few know or appreciate them. There are dozens of living lakes, said to be bottomless, within 5 miles of my ranch, abounding in fish, and from several of which water is flowing above ground into the Rio Pecos.

I am very much interested in any enterprise which will tend to utilize the immense amounts of water now (sometimes seeping and sometimes rushing) being wasted through subterranean channels, only feeding the Rio Pecos, a great sized monster already gorged, when thousands of acres of arid lands, unappropriated, are gaping with parched jaws for that wasted substance which would clothe them with verdure. I have ever done what I could for any promising scheme which pointed in this direction. I am proud that I was a factor, in its incipiency, in the success of The Pecos Irrigation and Investment Company. It is a success, past a peradventure. These companies have seized what is in sight, but there is a mine beneath our feet.

I have pondered over this artesian water business for some years. What has always held me back was the expense; so much heavier here than where they possess railroad facilities. We are about 200 miles from any railroad; there is one in course of construction that will relieve us, without doubt. I would like to correspond with you upon this subject of artesian wells. Do you not think Government might assist a private enterprise where ample guaranties are offered?

I have mentioned that some streams supply water for a certain number of farms. In explanation I will say that from 60 to 80 acres in cultivation is considered a fair farm in this section.

REPORT OF F. E. ROESLER, DIVISION FIELD AGENT FOR TEXAS.

The following observations, prefatory to my detailed report on the artesian and underground water supply of the State of Texas, west of the ninety-seventh meridian, made by me pursuant to instructions, are respectfully submitted:

ARTESIAN FLOWING WELLS.

West of the ninety-seventh meridian there are, in all, between 650 and 700 flowing wells, ranging in flow from 1 gallon to 1,000 gallons per minute, and in depth from 15 feet to 1,852 feet, and in cost from $25 to $7,200. The greatest number of flowing wells are situate in the counties of Bosque, Somervell, Tarrant, and Hood, and in these the average depth is from 200 to 500 feet, a few exceeding this depth. The average flow is between 10 and 20 gallons per minute, a limited number reaching 60 to 100 gallons, and a few exceeding this; some reaching a flow of 300 gallons per minute. The largest wells in the State are those at Waco, 5 of which jointly flow about 5,000,000 gallons per diem. All of the flowing wells except 31 are situate east of the one hundredth meridian, and as a factor in irrigation at present, count for little or nothing. Good palatable water is found at comparatively shallow depth only east of the ninety-ninth meridian, and north of a line drawn, say from the southwest corner of Bandera County to Aransas Pass. South of this line and west of the ninety-ninth meridian as far as the one hundredth meridian, all the flowing water obtained from well is impregnated with salt, coal oil, gas, and various compounds of soda, sulphur, gypsum, and is generally unfit for irrigation or any other purpose. The wells east of the ninety-ninth meridian are in material that a non-geologist would locate as underlying the coal measures, while the mineral wells are in the coal measures and partake of all the evil smells and flavors that these strata afford. As a rule good water (flowing wells) can be obtained anywhere east and north of the coal measures at a depth not exceeding 1,000 feet. A flow of 10 to 100 gallons per minute can be obtained at from 200 to 500 feet, with an increase of flow as the depth is increased. South of the line from Bandera County to Aransas Pass, and west of the ninety-ninth meridian, flowing water is found at a depth of 500 to 1,600 feet, but bad water is encountered at 50 to 100 feet and does not appear to improve at greater depth, though the well-borers and others claim to a man that there is good water in the last deposit of water that was struck in nearly every well that I examined. I confidently believe that there is much truth in the assertion, knowing that until within the past two or three years there was not an apparatus in the State that was adapted for deep borings, and that most of the men were new in the well-boring business, and that a majority of failures were due to inexperience and the improper tools used.

West of the one hundredth meridian as far as the Pecos River, in what might be called the "semi-arid region," there are a few flowing wells, none of which are over 150 feet deep and all of which were found accidentally. There are 3 in Hockley County, 1 in Dallam County, 1 in Lubbock, and 1 in Midland County. The flow from any of them is insignificant, except that in Midland County, and this well is more of a spring or underground stream than a well, presenting a feature not common to the rest of the county.

In the arid region west of the Pecos River, in Reeves County, there are 26 flowing wells. Twenty-four wells are at Pecos City, varying in depth from 185 feet to 300 feet, and in flow from 20 gallons to 300 gallons per minute. Twenty-two miles west of there, at Toyah Station, are 2 flowing wells, one of which is 832 feet deep. The flow from this well is 300 gallons per minute. The water contains sulphur, but judging from the appearance of a 5-acre garden irrigated from it, the water is beneficial rather than otherwise to plant life.

As to whether or not flowing wells can be used to advantage in irrigation, I think it is simply a matter of capacity and relative cost as well as locality. Taking the equivalent of 36 inches of rain-fall as the maximum quantity of water required to produce a perfect crop, the duty of flowing wells in different localities will be about as shown in table below.

The growing season in Texas varies in length in accordance with altitude and latitude. South of the thirty-first degree of latitude the growing season may be said to last from the 1st of April to the 1st of December, as frosts are rarely encountered between these dates. North of this latitude it might be safe to figure from the middle of April to the middle of November, both of these limits being good east of the one hundredth meridian. For the Pan Handle and the western part of the State to the Rio Grande, the growing season may be fixed as beginning about the 1st of May and ending about the 1st of October, no serious frosts being expected within these dates. The length of the growing season is such that with proper facilities for irrigation the farmer is enabled to produce more than one crop during the season.

The time in which irrigation can be applied to best advantage varies with the altitude and may be given at about as follows: Between the ninety-seventh and ninety-ninth meridians, June, July, and August; between the ninety-ninth and one hundred and third, March, April, and July; west of the one hundred and third, at all times during the growing season. The dryest weather in central Texas is in midsummer, and the dryest in the Pan Handle and Staked Plain in winter and early spring. The rainy season of the Trans-Pecos country is in June, July, and August.

Irrigating capacity of flowing artesian wells.

Capacity of wells per minute.	Between 97th and 99th meridians, altitude 700 to 1,500, minimum rain-fall 27 inches. Amount of water to be supplied is 9 inches, or 244,386 gallons per acre.*	Between 99th and 101st meridians, altitude 1,500 to 2,400, minimum rain-fall 20 inches. Amount of water to be supplied is 16 inches, or 434,464 gallons per acre.†
Gallons.	*Acres.*	*Acres.*
5	10.2	5.9
10	21.2	11.8
20	42.4	23.6
40	84.8	47.2
60	127.2	70.8
100	212.0	118.0
300	636.0	354.0
500	1,060.0	590.0
1,000	2,120.0	1,180.0

* Allotting the equivalent of a 3-inch rainfall only three irrigations of 81,462 gallons are necessary for each acre, and if the water is stored this can be easily done.
† This will allow five irrigations of 3⅕ inches, or 86,893 gallons for each acre.

Capacity of wells per minute.	Between 101st and 103d meridians, altitude 2,400 to 3,100 feet, minimum rainfall 16 inches. Amount of water to be supplied is 20 inches, or 543,080 gallons per acre.*	Between 103d and 106th meridians, altitude 3,100 to 6,000 feet; rainfall not taken into consideration. Amount of water to be supplied is 36 inches, or 977,544 gallons per acre.†
Gallons.	*Acres.*	*Acres.*
5	4.7	2.6
10	9.4	5.2
20	18.8	10.4
40	37.6	20.8
60	56.4	31.2
100	94.0	52.0
300	282.0	156.0
500	470.0	260.0
1,000	940.0	520.0

* This will admit of six irrigations of 3⅓ inches, or 90,513 gallons for each acre.
† This will admit of twelve irrigations of 3 inches, or 81,462 gallons for each acre.

Remarks.—The within estimate is made on the basis of allowing each acre the equivalent of a 36-inch rain fall each year. Whatever falls naturally is counted in, and only the difference between the actual minimum rainfall and the total allowance is supposed to be supplied by irrigation. The annual duty required, between meridians 97 and 101, of the wells will vary greatly with each year. Fine crops are grown without irrigation, and in some years the crop is as perfect as it can be on unirrigated land. The yield could, however, be greatly increased and crop-making made more certain by irrigating. In the ordinary run of years the same wells will probably irrigate more land than above estimated, and only in an exceptionally dry year will the limit of capacity be reduced to the figures given. Between meridians 101 and 103, the equivalent of a 12-inch rain fall is, in ordinary years, ample and sufficient. Two or three irrigations during the year are generally sufficient for vineyards and orchards. In order to provide for a drouthy year, I have allowed 20 inches.

PROFIT OF ARTESIAN WELL INVESTMENTS.

As to whether or not an artesian flowing well will pay as an irrigation investment depends upon several things: First the cost, and second the capacity.

A flowing well, say in Stephens county, 200 feet deep, costing $200, flowing 5 gallons per minute, and irrigating 10.6 acres, ought to pay, if an annual water rental of $2 per acre can be obtained. This would yield an annual income of $21.20, over 10 per cent. of the cost per annum. If the same well were 500 feet deep and had cost $500, it would barely pay low interest on its cost. If the same well, costing $200, yielding only five gallons per minute, and irrigating only 2.6 acres, as it would in the trans-Pecos country, it would not pay. A well at Pecos City, costing $600, flowing 100 gallons per minute, will irrigate in that country 52 acres. Figuring at $2 per acre for water rent, the income would be annually $104, or 17.3 per cent. This well would pay. In Bosque County the same well would irrigate 212 acres, and allowing only $1.00 per acre for annual water rent, the income would be $212, or 35.3 per cent. on the cost.

The advertised capacity of the five flowing artesian wells at Waco is given at 5,000,000 gallons per diem, and the cost of the same is approximated at $32,000, it being admitted by the owners that at the present time the same wells could be bored for much less money.

If these wells were used for purposes of irrigation they would have the following capacity: Their annual flow would be 1,825,000,000 gallons. This quantity would irrigate at Waco, allowing 9 inches of water for each acre, 7,467.6 acres. A water rent of $1 per acre would pay $7,467.60 on the money invested, or 20.21 per cent. The same plant used between meridians 99 and 101, allowing 16 inches of irrigation water to each acre, would irrigate 4,200.3 acres, which at an annual water rental of $1 per acre would yield $4,200.30, or 13.4 per cent. on the investment. Between the meridians 101 and 103 more water per acre will be required, say about 20 inches per annum. The water would be used for growing the raisin grape and the finest of California fruits. The user of the water could readily pay $2 per acre annual water rent.

In this region, which includes the Pan Handle and the Southern Staked Plain, the Waco plant would irrigate 3,360.4 acres. The annual rental would amount to $6,720.80, or 21 per cent. of the cost of the plant. In the trans-Pecos country, or arid region, where the allowance per acre is the equivalent of a 36-inch rainfall, the duty of this plant would be 2,080.8 acres. The annual water rent, at $2 per acre, would amount to $4,161.60, or 13 per cent.

In the estimate of water to be furnished each acre, the evaporation does not enter into the calculation. East of the trans-Pecos country it is an unknown quantity, changing with the weather, and compensating itself by the dews and rainfalls between times. For the trans-Pecos country the allowance is liberal enough to provide for the evaporation. The estimate of capacity is based on the supposition that each farmer or fruit grower will have storage reservoirs on his place sufficient in capacity to hold the equivalent of 3 inches of rainfall for each acre. The deeper this reservoir and the greater the quantity of water held in storage in one place, the less will be the evaporation to the square foot. If due care is given to the storage, namely, the reduction of the surface to the minimum area, the better are the prospects of reducing the evaporation to the minimum quantity. The amount of evaporation will depend greatly on the depth of the reservoir and its surface area.

From the observations given above, I feel safe in saying that the artesian flowing well will become an important factor in irrigation, not only in the arid part of Texas, but also in the humid and subhumid localities, as soon as its value becomes known. I believe that my estimates are conservative, both as to duty of the wells and income derived. An artesian-well plant that can supply 100 fruit farms of 20.8 acres each with 36 inches of water is a grand success when it yields 13 per cent. annual interest on its cost. This plant at Waco cost about $32,000.

It would pay as an investment if the plant cost $64,000, for then it would still be bearing 6½ per cent. interest on its cost. Now, in the Pecos Valley, I am satisfied, a flow of 1,000 to 3,000 gallons per minute can be secured from 8 or 10 inch wells at a depth of 1,000 to 2,000 feet. At the town of Pecos, flowing water under considerable pressure is found at 185 to 300 feet. At Toyah, 20½ miles west and 385 feet higher, this water is encountered at the same depth, but does not flow. At 832 feet is a strong flow of 300 gallons per minute, containing sulphur, but it is claimed that the bottom water is pure, and that the sulphur water comes from above, and that the flow would be pure if the well was properly cased. Now, if the same deposit of water were pierced at Pecos City the pressure would be increased by the weight of a column of 385 feet, or about 146 pounds to the square inch.

The artesian belt of the Pecos Valley extends probably from the mountain ranges of central New Mexico and the mountain ranges in Texas, 40 to 60 miles west of the river, to the Davis Mountain in Pecos County, say a territory 40 to 80 miles wide and from 200 to 300 miles long. In this region there is a tremendous underground flow trending southeastwardly, and deserving a most careful investigation. Its course is but indistinctly outlined, but I am inclined to believe that it flows eastwardly and southwardly from the Guadaloupe and other ranges until it reaches a barrier formed by the Davis Mountains. Here the vast stream is turned eastwardly, passing along the southern edge of the Staked Plain to about the one hundred and first meridian, where it divides into numerous underground rivers, which form the springs of the Concho, San Saba, Llano, Hondo, Frio, Leon, Salado, Guadaloupe, San Antonio, San Marcos and numerous other rivers of southeastern Texas.

As to the water supply west of the Guadaloupe, Davis, Carrizo, Diabolo, and other mountain ranges, it can only be said that the surface supply is scarce—very scarce, in fact—and that the railway borings do not promise much in the way of an abundant supply of water for irrigation either from artesian or common wells. Professor Steeruwitz, who has made a geological examination of the country, gives it as his opinion that flowing wells will never be found in the great prairies lying between the different mountain ranges.

On the other hand, old residents and practical well-borers whom I have consulted do not concur. They reason that the forces which were sufficient at some remote period of time to throw up the mountain ranges were also sufficient to tear up the country lying around and between the different ranges. They give it as their opinions that the mesas were, immediately after the disturbance that formed the mountains, very broken and hilly; that underneath their smooth surfaces, as now seen, are hills and valleys, river channels, and lake basins; and that afterwards, by erosion, the mountains were reduced in size and the lower-lying lands filled up with the débris, and that it is not at all improbable but that by systematic efforts vast quantities of water will be found under these mesas—some held in suspense in old lake basins,

some flowing in underground streams, and other supplies held under pressure—that would rise to the surface if penetrated.

It is held, also, that there is an underground stream of great volume which works its way under the bed rock and flows southwardly and southeast; that it originates in Colorado and New Mexico, flowing southerly until it reaches the southern extremity of the Organ Range; it then passes between the Organ Range and the Franklin Mountains, and again between the Franklin and Hueco Mountains, flowing eastwardly until it is diverted southerly by the Quitman Range, where part of its waters are emptied into the Rio Grande.

The existence or nonexistence of this underflow should by all means be determined, for on its existence depends the irrigation of perhaps a million acres or more of its rich fruit and farming lands. Those who have more carefully examined into the water supply, among them Major Logan, of Fort Hancock, Tex., believe that flowing wells can be obtained wherever this stream can be penetrated. It is not improbable but that in a number of valleys or plains lying between parallel ranges trending north and south a similar underflow will be found.

In the southeastern part of El Paso County and in Jeff Davis, Presidio, and Pecos Counties are several mountain ranges that seem to cut off the underflow from the country south of them. As shown by the well borings in that section, the water lies very deep, the supply is scant, and the wells show no artesian characteristics. The whole of the trans-Pecos district is worthy of a most careful survey, and the work now begun should be carried on systematically until the course, direction, and quantity of the underground flow has been well determined. The Pan Handle and Staked Plain of Texas offer an immense field for further investigation, as 85 per cent. of the common wells dug and bored in this region show indications of artesian origin of the water.

The deepest well in this vast territory is only 800 feet deep, and resulted in failure, owing to inadequate machinery and inexperience of the parties doing the work. Of the many persons whom I have consulted, and who were perfectly familiar with the water supply of this part of Texas, all were of the opinion that flowing water could be obtained at 1,000 to 1,500 feet depth, and further, that the water would be free from obnoxious mineral ingredients.

Water in abundance is obtained in common wells at a depth of 20 to 150 feet, and 200 feet in a few instances. Along the southern and eastern edges of the Staked Plain are thick deposits of a red joint clay which have been penetrated to a depth of 400 and 700 feet and no water obtained. It is believed that there is flowing water below and north of them, and that these deposits act as a retaining wall, diverting the underflow of the Staked Plain and country north of it to the eastward.

It will be noted that there are no streams of water issuing from the southern end of the Staked Plain, and that there are no streams in either Ward, Crane, Upton, or Crockett Counties that flow from the north or northwest, the nearest flowing surface water being the North Concho, along the east line of Glasscock county. East of the plain are the various tributaries of the Colorado and Brazos, all of which derive their water from either the Pan Handle or the Staked Plain. Between the one hundred and first and one hundredth meridians, or rather from the edge of the Staked Plain to the one hundredth meridian, salt has been found in the deep wells. It generally lies deep enough not to interfere in common wells, but in boring for flowing wells to a depth of 600 to 1,000 feet, as at Colorado City and Big Springs, beds of rock salt have been encountered at a considerable depth.

At Colorado the brine obtained is used in the manufacture of salt, and at Big Springs the water (salt) comes to within 3 feet of the top of the well. It is claimed for the four wells bored at Colorado, 1,000 to 1,200 feet deep, and the one at Big Springs, 603 feet deep, that the bottom water in each is pure, and that by boring a few hundred feet more a flow of good pure water would have been obtained. In the tier of counties immediately west of the one hundredth meridian there are, in places, large deposits of gypsum, which in a number of wells make the water unpalatable, but which would nevertheless be useful for irrigation. Good water is found in a majority of the common wells, but occasionally the water is strongly impregnated with "gyp."

Between the ninety-ninth and one hundredth meridians, and extending south from a line drawn from northwest corner of Bandera County to Aransas Pass, mineral, salt, oil, soda, sulphur, etc., have been found in most of the deep borings, and a majority of the flowing wells have the same characteristics. The flowing wells vary in depth from 500 to 1,000 feet, but it is also claimed that there is good water below, that all the impurities are from upper layers, and that if the wells were properly cased good water would be obtained.

In some counties, like Eastland, Palo Pinto, and a considerable number of others, salt or mineral water is obtained at 30 to 60 feet, and water for household uses is stored in cisterns. In nearly all these counties there are thousands of locations for small storage reservoirs, varying in area from one-half acre to 60 acres. Many of the ravines are worthless for agricultural purposes, and could be put to excellent use in this manner. As a rule, the soils are composed of a clay that is excellently adapted to the construction of dams, and when built of this material they will hold water like a jug. If it should be definitely determined that flowing wells of good irrigable water can not be secured, this section of Texas can nevertheless be converted into a magnificent farming country by the construction of dams alone. The rainfall is ample and sufficient on the sandy loams in this region, but the clayey soils shed more water, and absorb less, in consequence of which the crops suffer more during the dry spell than they do on sandy soils. The wells, where they are situate on clay lands, dry out, while the wells in sandy lands are lasting during a drought. There are very few farms on the clay lands where a reservoir could not be built with a few days' labor.

If all the farmers between the ninety-seventh and the one hundredth meridians would devote more of their time to constructing storage dams than to regulating railroads, they could completely change the climate of this region. The water detained in the reservoirs during the rainstorms would not reach the hundreds of creeks that are dry half the year, and angry torrents the other half. Every year several million dollars are lost through disastrous overflows, all of which could be avoided. The seepage from these thousands of tanks or reservoirs would keep water in the wells, create thousands of springs where there are none now. The creeks would, in consequence, carry water all the year. If necessary to irrigate, the water would be at hand, but the probabilities are that if everybody had a "tank" the evaporation from these numerous bodies of water would bring about such an inequality in the temperature of the region that summer rains would be the order of the day, whereas now they are of rare occurrence at the time when most needed, namely, in June, July, and August, at which time corn, cotton, and fruits need rain the most. Between the one hundredth and one hundred and third meridians the construction of thousands of "tanks" or reservoirs would also have a most beneficial effect. The rainfall is

most needed there in March and April, when winter wheat is stooling. The weather is generally warm enough to give the crop a good start, if it had the necessary moisture. If one single irrigation could be then applied, or a single rainfall induced by the evaporation from these tanks, the wheat crop would average 40 bushels instead of 20. As the rainfall is nil during December, January, and February, the rainfall of September, October, and November must be stored, and where this is insufficient, it must be reënforced by artesian flowing wells or common wells with windmill attachments.

Between the ninety-seventh and ninety-ninth meridians flowing water can beyond doubt be obtained almost anywhere at a depth of 500 to 1,000 feet, but to secure a large flow, say 1,000 gallons per minute, the depth will have to be between 1,500 and 2,000 feet. As the presence of artesian water in great quantity at 1,852 feet has been found at Waco, a number of Texas cities, like Cleburne, Dallas, Fort Worth, Sherman, Abilene, El Paso and a number of others, have been sufficiently encouraged to raise the necessary capital to bore 2,500 feet, if necessary, to secure a similar flow.

Between the ninety-ninth and one hundred and first meridians the borings have been failures throughout. In most cases, as at Cisco, Eastland, Baird, Colorado, and Big Springs no flow was secured, leaving the few small shallow wells at Wayland, Stephens County, out of the calculation on account of their small flow. Where a flow has been secured, it was either mineral, as at Cotulla, La Salle County; impregnated with salt, coal gas, etc., as at Trickham, Coleman County; Gordon, Palo Pinto County; San Antonio, Eden, Concho County, and other places. The pressure necessary for artesian wells is present in all the wells mentioned.

The general opinion of the residents is that the artesian deposit is good water, and that the obnoxious ingredients come in from the upper layers, and that the work of boring, in most cases, is badly done. Knowing, as I do, that first-class drilling rigs have only been introduced in the State within the past two years, I believe that there is much truth in the statement and do not hesitate to give it as my opinion that a flow (over 500 gallons or more per minute) can be secured at a depth of 1,800 to 2,000 feet, and guided by the opinions of others I think there is a reasonable prospect that the water will be of good quality if the upper water deposits are carefully cut off. If the water contains gypsum or sulphur it will not be injurious to plant life and can be used for irrigation. A flow of 300 gallons per minute ought to furnish the equivalent of 16 inches of rainfall to 354 acres between meridians 99 and 101, which ought to be worth $2 per acre, water rent, to the consumer and should pay $708, or 17.7 per cent. interest on the cost, supposing the well to be 2,000 feet deep and to cost $4,000. The $708 would be 10 per cent. interest on $7,080, or 5 per cent. on $14,160. There is sufficient margin to secure a paying interest on the capital invested at either figure.

On the Staked Plain and Pan Handle, meridians 101 to 103, the same well would irrigate 282 acres, 20 inches deep, and in the Trans Pecos country 156 acres, 36 inches deep, where it would, at the same water rent per annum, pay 7.8 per cent. on $4,000, or 3.9 per cent. on $8,000, capital invested, with chances in favor of the investor of securing double and triple the flow, and increasing thereby the income in the same proportion.

The section of Texas in which the artesian flowing well question is unsettled, is all that part lying west of the ninety-ninth meridian. The

people there have done what they could with their limited means. To them a sufficient water supply means everything, but, with the exception of the town of Abilene, they are unable to make such borings as there should be made. They can not contract for borings deep enough to induce men with suitable machinery to come to Texas and do the work, and then to have to stop several hundred feet from good water because the money gives out means disheartening failure. If one flowing well with good water is secured, flowing 300 to 1,000 gallons per minute, and it is proven beyond a doubt that the water is there, no trouble will be met with in securing all the money wanted to bore hundreds of flowing wells thereafter.

In presenting a condensed review of my observations* I submit also the conclusion I have arrived at; that I have seen enough to warrant the statement; that a further examination of the underground water is essential to the prosperity of the agricultural population of our western country, and that the work now begun should be vigorously carried on, as it can not fail to settle and dispose of many vexatious questions affecting our national prosperity, as well as the individual welfare of the tiller of the soil. Any farm with 10 acres under irrigation would support a family in time of drouth. There may be no profit made in a drouthy year, but the farmer will not have starvation staring him in the face. If the National Government can bring about this condition on our western farms, by disseminating information, by locating the underground water supply, and teaching the people its value, and the most economical means of applying it to their lands, the crowning work of the century will have been accomplished. I therefore venture to make the following:

RECOMMENDATIONS.

That as the farmers of the subhumid region, including all that country lying between the ninety-seventh and one-hundredth meridians and the Gulf of Mexico, and the British Possessions, suffer annually to the extent of several hundred million dollars in the loss of yield in crops, caused by virtue of excessive rain-fall in one part, and by drought in another part of the growing season, and that these losses can be greatly diminished by providing proper means for drainage and irrigation, and also that the subject of drainage and irrigation is but little understood by the farming population of this portion of the country; that there should be printed and distributed, at the expense of the National Government, a million or more copies of a pamphlet to be prepared by the Department of Agriculture, treating on the subject of drainage and irrigation; and to be printed in the common vernacular of the country; and be as free as possible from technical, or local terms. This pamphlet to contain information as to the most economical methods of draining and irrigating ordinary farm lands; of utilizing the drainage for irrigation when needed; of constructing drainage ditches, irrigation ditches, flumes, storage dams, and storage reservoirs to irrigate from 1 to 1,000 acres; to cost and details of constructing common wells and methods of raising and applying the water; the capacity of wells with regard to acreage and the details of actual irrigation, showing how and in what manner

*Mr. Roesler submits on his own responsibility the following conclusions and recommendations. They are given in this wise, then, as those of a man of keen intelligence, highly trained in the work called for by this inquiry but without the committal of the Department or the artesian wells investigation.

the water is applied to the land, and such other information that is germane to the subject.

The pamphlet to be issued free of cost to any farmer who will apply for a copy to his Representative or his postmaster, or to the Secretary of the Department of Agriculture if resident west of the ninty-seventh meridian.

I would further recommend that the country lying west of the one hundredth meridian and east of the Rocky Mountains, extending from the Rio Grande River to the British Possessions, be divided into districts 100 miles long and wide, and that in each such district there be placed an observing corps, to consist of a topographical engineer, a gardener, and a testing crew consisting of a practical well-driller and assistants; that such corps be furnished with appliances as may be necessary to make a thorough series of water tests.

Within each such district there will be found large expanses of territory that are sufficiently level to be irrigated and that have a rich soil that needs only water to make it fertile. If the Government tests prove water in sufficiency to be present, and that it can be brought to the surface at reasonable cost, either by artesian pressure or by suitable pumping machinery, private capital will soon populate such territory by providing the means of securing and raising the water and enabling the settler to utilize it.

In connection with water observations I would also respectfully recommend that within each of such districts a small experimental farm, 20 to 40 acres, be maintained by the Government, and that a special effort be made to determine the limit of profitable culture of the standard crops, such as wheat, corn, cotton, rye, barley, oats, fruits of all descriptions, vegetables, forest trees, fibrous plants, etc. The tests should be made to ascertain the limit of altitude in which any of these crops can be grown; also there should be determined the limit of endurance of the various crops under stress of dry weather, the limit of drowning or rot by excessive irrigation, and there should also be ascertained, in each locality, the maximum and minimum quantity of water necessary to mature profitably any crop. The various methods of irrigation, with a view to economize in the use of water, should be tried and reported on in each district, and the information obtained be published for the benefit of the people.

PART II.

THE TEXAS DIVISION.

The territory comprising the Texas division of the United States artesian wells investigation includes all of that part of Texas lying west of the ninety-seventh meridian, or a line drawn from Red River, at a point about five miles west of the boundary line between Grayson and Cooke Counties, to another point about one mile east of Aransas Pass lighthouse on the gulf coast. The area of this territory is about 215,156 square miles.

For convenience of description this territory has been divided into three districts, bounded arbitrarily by the meridian lines, though this division can not be said to be strictly correct for the reason that the rainfall is largely governed by the altitude, which is not uniform along the meridians. The districts are described as follows:

Subhumid region, district No. 1.—All that part of Texas lying between meridians 97 and 100 and between Red River and the Rio Grande and the Gulf of Mexico. Area about 99,811 square miles.

Semi-arid region, district No. 2.—All that part of Texas lying between the one-hundredth and one hundred and third meridians, and the public land strip on the north and the Pecos River where it crosses the one hundred and third meridian southeast to its junction with the Rio Grande and along the Rio Grande to the one hundredth meridian. Area about 83,725 square miles.

Arid region, district No. 3.—All that part of Texas lying west of the one hundred and third meridian from southeast corner of New Mexico to Pecos River, all counties lying west and south of Pecos River, north of the Rio Grande and south of the south line of New Mexico. Area about 31,620 square miles.

DISTRICT NO. 1.

District No. 1 embraces eighty-seven counties, varying greatly in altitude, rainfall, and general characteristics. Along meridian 97 the altitudes vary from sea level at Aransas Pass to 722 feet at Denison on Red River, about 25 miles east of said meridian. On the same line according to report of Texas commissioner of statistics for 1882, the rainfall varies from 35 to 39 inches. Along the ninety-eighth meridian the altitudes vary from 33 to 55 feet above sea-level at the Rio Grande to 915 feet at Henrietta, in Clay County, on Red River, and the rainfall varies from 26 to 36 inches. Along the ninety-ninth meridian the altitudes range from 521 feet at Ringold Barracks on the Rio Grande, to 1,611 feet in Eastland County, and probably about the same at Red River. The one hundredth meridian crosses the Rio Grande at an altitude above 800 feet, reaching 932 feet in Uvalde County, 2,060 feet at Fort McKavett, in Menard County, 2,120 feet at Fort Chadbourne, in Runnels County, and higher altitudes further north, while the rainfall varies from 18 inches to 26 inches. Both the Southern Pacific and the Texas and Pacific Railways traverse the district from east to west. The altitudes on the Southern Pacific Railway are as follows: Flatonia, 461; Waelder, 375; Harwood, 460; Suling, 416; Kingsbury, 613; Seguin, 599; Marion, 649; Converse, 717; San Antonio, 686; Dunday, 1,008; Houdo, 900; Sabiual, 963; Uvalde, 930. The altitudes on the Texas and Pacific Railway are as follows: Dallas, 466; Fort Worth, 629; Weatherford, 870; Brazos River, 750; Gordon, 875; Strawn, 900; Ranger, 1,425; Eastland, 1,500; Cisco, 1,625; Baird, 1,700; Clyde, 2,025; Abilene, 1,700; Merkel, 1,875. A list of altitudes along the lines of the Fort Worth and Denver Railway and the Gulf, Colorado and Santa Fé, and other railways was requested but not furnished.

As the subject of the inquiry relates more particularly to artesian wells, report is first made of those known to exist. The information obtained is fragmentary and incomplete, owing to lack of time to make a thorough research. The information obtained can not be well tabulated, so as to give anything like accurate total results, but will show nevertheless that the question of securing water by means of artesian wells, receives due consideration in Texas.

An act of the legislature of Coahuila and Texas (then a part of the Republic of Mexico), passed in October, 1827, shows that the idea of boring for water existed and was encouraged at that early day, though nothing came of it for nearly half a century. The act reads as follows:

> Leon R. Almy shall be permitted to introduce and establish in the State a boring-machine to cause water to flow spontaneously to the surface. For the term of six years from this date no other person shall establish machines of this description without the previous consent of the said Almy, that he may indemnify himself for his expenses and receive the compensation he deserves for his trouble.

In April, 1857, the legislature of Texas contracted for the boring of an artesian well on the capitol grounds. The report on the well made July 1, 1859, by Prof. B. F. Shumard is as follows, regarding the different strata passed through:

Depth July 1, 1859, 471 feet.

	Feet.
No. 1. Soil and subsoil	5
No. 2. Soft, white chalky limestone, disintegrating more or less rapidly on exposure to the air	18
No. 3. Moderately hard, bluish-gray and cream-colored argillaceous limestone, containing teeth and scales of fishes, *Inoceramus* (*Trichites*), *Lerouxii*, *Ammonites*, and other fossil remains	94
No. 4. Dark, bluish-gray, indurated marl	14
No. 5. Compact, bluish-gray limestone	31
No. 6. Blue, marly clay, with fossil shells, coated with iron pyrites, chiefly *Exogyra arietina*, *Ianira*, and *Dentalina*	70
No. 7. Hard, dark, bluish-gray, earthy, pyritiferous limestone and shale, containing *Exogyra arietina*, *Gryphæa pitcheri*, *Ianira*, and *Taxaster*. Many of the fossils of these strata are wholly or in part composed of iron pyrites	47
No. 8. Blue, sandy, argillaceous limestone with fossils like those of No. 7	25
No. 9. Soft, earthy, sandy, fine-grained limestone of a dull gray hue	6
No. 10. Indurated, bluish-gray silico-magnesian limestone, containing a good deal of sulphuret of iron	6
No. 11. Grayish-white, earthy, fine textured sandy limestone (magnesian ?) with *Taxaster* and *Exogyra*	13
No. 12. Bluish-gray, sandy magnesian limestone, with thin marly partings and abounding in organic remains—*Exogyra arietina*, *Gryphæa pitcheri*, *Ianira*, and *Dentalina*, and fish teeth. Many of these fossils are coated with sulphuret of iron, which gives to them an elegantly bronzed appearance	48
No. 13. Gray, earthy limestone, of a fine sandy texture, with gypsum, nodules of flint, and masses of iron pyrites, and containing also a few organic remains, chiefly *Exogyra* and *Taxaster*	94

At the depth of 323 feet, a vein of mineral water was struck, which rose within 40 feet of the surface. A qualitative chemical analysis of this water by Prof. W. P. Riddell, chemist of the Geological Survey, shows it to contain the following constituents, named in the order of their relative abundance:

[Texas Almanac 1860.]

Chloride of sodium.
Bicarbonate of lime.
Sulphate of—
 Lime.
 Soda.

Sulphate of—Continued.
 Alumina and potassa.
 Magnesia.
 Iron (a trace).
Sulphureted hydrogen.

I have not been able to ascertain whether or not this well was ever completed, or if a flow has been obtained.

Modern flowing wells.

County and post-office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Atascosa County:		*Feet.*	*Feet.*		
Pleasanton	Nic Bluntzer	......	350	$600.00	10 gallons.
Baylor County—Artesian water found at Seymour, at a depth of 216 feet; flow strong.					
Bexar County:					
San Antonio	Crystal Ice and Manufacturing Co.	683	650	$2,000.00	840 gallons, soft.
Do	....do	......	815	....	400 gallons.
Do	....do	......	650	....	840 gallons, soft.
Do	....do	......	....	....	100 gallons, sulphur.
Do	Caroline Kampmann	......	465	1,500.00	25,000 gallons in 24 hours.
Do	West End Town Co	......	260	500.00	Two artesian wells. Flowing 150 gallons per minute. Just runs over top.
Do	F. M. Rowe	......	675		

Modern flowing wells—Continued.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
		Feet.	*Feet.*		
Bosque County:*					
Meridian	J. J. Lumpkin	791	450	$600.00	45 gallons.
Do	City of Meridian	791	580	1,000.00	24 gallons.
Do	Dr. J. J. Lumpkin	791	500	800.00	45 gallons.
Do	S. H. Lumpkin	791	525	600.00	Do.
Iredell	Public well	881	345	450.00	28 gallons.
Kopperl	A. W. Childress	574	525		
Morgan	M. & S. Logan	734	800		50 gallons.
Kimball	Jas. Holder		600		
Coyote	L. W. Chase				
Meridian	Jas. M. Roberson	791			
Walnut Springs	Koss Barry	901			
Cranfill's Gap	W. M. Smith				
Iredell	R. A. Rimer	881			
Do	N. Bryant				
Meridian	Henry King	791			
Valley Mills	S. V. Pool	592			
Meridian	S. J. Siddall	791			
Eulogy	Eulogy Well Co		529	850.00	30 gallons.
Brazos Point	O. M. Adison				
Do	A. Wamble				
Do	P. W. Williams				
Eulogy	A. G. Walker				
Do	J. H. Osborn				
Do	J. E. Brown				
Morgan	Muirhead Water Co.	734	585	1,000.00	18 gallons.
Do	do			550.00	18 to 20 gallons.
Eulogy	S. E. Moss		780		50 gallons.
Morgan	R. P. Lowe		600		5 gallons.
Do	J. L. White		580		18 gallons.
Morgan, 12 M. East.	S. E. Moss		501		100 gallons.
Do	do		501		Do.
Burnet County:					
Oakalla	J. C. Kincaid		100		1 gallon per minute.
Do	L. S. Hine		100		

J. M. Kincaid, Oakalla post-office, reports three wells within one-half mile of each other, and all less than 100 feet deep; flow 20 to 40 gallons per minute.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Coleman County:					
Frickham	L. L. Shield		220	$400.00	Salt water.
Concho County:					
Eden	Mallory Cattle Company.		987		Small flow of salt water.
Coryell County:					

There are in Cowhouse Valley about fifty flowing wells, one at depth of 320 feet that flows 50 gallons per minute. The other wells stop at the first strata of flowing water. If wells were 100 feet deeper they would all run from 5 to 75 gallons per minute. None of these wells have more than 30 feet casing, and there is much water wasted * * * These wells can be drilled for $200.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Pidcock Ranch	J. F. Meek		252	$200.00	Quantity of flow not given.
King	L. McCleskey		240	240.00	2 gallons.
Pecan Grove	J. M. Davidson		220	253.60	½-inch stream.
King	J. T. Webb				
Do	L. S. Sargent				
Do	James Gidion				
Do	James Barham				
Pidcock Ranch	J. F. Barham				
Do	Eli Williamson				
Do	W. L. Bridges		290	500.00	1 to 5 gallons per minute.
Do	H. S. Perryman				2½ gallons per minute.
Do	W. H. Belcher				
Gatesville	W. Carlisle				
Dallas County:					
Dallas	J. J. Brick	466	700	1,800.00	12 gallons.
Do	City park well		672		15 gallons.
Arlington	On M. C. Hill place		120		3-inch pipe flowing.
Do	T. J. Murnane's place		15		Dug well overflowing.
Do	A. Rust's place		15		Do.
Do	A. Bass' place				3-inch bold stream.
Dot					
Denton County:					
Denton	Texas and Pacific Railway.				
Do	Alliance Milling Company.		415–600		All flowing strong streams.
Do	Denton Ice Company.				
Do	Denton Mill and Elevator.				

A number of flowing wells in the county.

* There are about one hundred and fifty artesian-flowing wells in Bosque County, generally used for ordinary farm purposes and watering live stock.

† From 50 to 75 flowing wells.

Modern flowing wells—Continued.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
		Feet.	*Feet.*		
De Witt County:					
Cuero	Judge J. D. Ferry	177			
Yorktown	S. S. Charles*	}	64	$60	8 gallons per minute.
Do	W. Eckhart				
Eastland County:					
Cisco, 4 miles northeast.	Texas, Georgia and Mississippi survey, 1888.	1,611			Flowing salt water and gas.
Eastland	A. Rawlins	1,299	400		Abandoned; flow of salt and mineral water.

NOTE.—Several flowing wells at Ennis and Midlothian.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Bandera County:					
Bandera	C. H. Thalmann				
Erath County:					
Thurber P. O	Texas and Pacific Coal Company.		960		Small flow, salt sulphur water.
Bluff Dale P. O	A. J. Glenn		165	400	
Do	A. M. Lauderdale	}	200–350	†2	Depth from 150 to 800 feet; all strong flowing wells; flow from 20 to 200 gallons per minute.
Do	Wm. Dunning				
Do	Geo. Jackson				
Do	Lauderdale & Greenwood.		128	100	
Frio County:					
Pearsall, 20 miles southeast.	T. A. DeVilbiss		158	273	3½ gallons per minute.
Do	T. B. Applewhite				
Do	C. H. Buve				
Do	T. A. & J. W. DeVilbiss.		260	$527\frac{50}{100}$	8½ gallons per minute.
Do	do		391	$910\frac{50}{100}$	6 gallons per minute.
Goliad County:					
Goliad, 7 miles northwest.	H. Shalper, county judge.	‡50	60	} 150	10 gallons per minute.
Do	do		60		
Grayson County:					
Pottsborough	Boring for coal		250	750	Flow constant and estimated at 250,000 gallons in twenty-four hours.
Do	do		250	750	
Do	do		250	750	
Do	do		250	750	
Hill County:					
Whitney, 1 mile east.	Coleman Carver	586			
Files	J. R. Lane		123	83	3 gallons per minute.
Hood County:					
A large number of flowing wells along Paluxy Creek.					
Paluxy	Cool Jackson		} 150–300	(§)	Flow from 5 to 50 gallons per minute.
Do	Isaac Moore				
Do	C. C. Meek				
Do	John Meek				
Do	W. S. Etheridge		236	250	50 gallons per minute.
Jack County:					
Jacksborough	A. Jasper	1,133	96	85	} Never failed to flow.
Do	do		130	130	
Gertrude	R. G. Harrell				
J. Thompson survey.	W. R. Garvin				
Johnson County:					
Virgil	L. P. Forbis				

About three flowing wells in the county and one now being bored at Cleburne. The deepest flowing well is 800 feet, the shallowest 600 feet; the flow is 15 to 20 gallons per minute.

Samuel E. Hays, of Waldrip post office, reports that in prospecting for coal a shaft was sunk 167 feet, 8 feet square, in which no water was found. "A drill was set in the bottom of the shaft, and at a depth of 100 feet (or 267 feet from surface) a strong vein of salt water was struck, which has nearly filled the immense cavity above of 8 feet square, and is still rising."

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
La Salle County:					
Cotulla	American Carlsbad Water Company.		1,008		"Several thousand gallons per hour."
McCulloch County:					
Waldrip	Coal prospectors		110		Flowing salt water.
Do	do		220		Do.

* Two wells bored 1876; both flowing.
† Per foot.
‡ Smithsonian Institution.
§ Seventy-five cents first 100 feet; $1 second 100 feet; $1.25 for third 100 feet.

Modern flowing wells—Continued.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
McLennan County:		*Feet.*	*Feet.*		
Waco	Bell Water Company (8 inches.)		1,834	7,200	750,000 gallons per diem.
Do	Bell Water Company (5⅝ inches).		1,834	5,000	306 gallons per minute.
Do	Bell Water Company (4¼ inches).		1,834		300,000 gallons per diem.
Do	do		1,834		Do.
Do	Waco Water and Power Company (8 inches).		1,812		1,200,000 gallons per diem.
McGregor					Strong flowing well.
Maverick County:					
Eagle Pass	W. A. Fitch	800	1,140		Flow of salt water and gas.
Hamilton County:					
Lanham			470		
Do			500		
Palo Pinto County:					
Gordon	Citizens of Gordon	822	485	800	1 gallon per minute, salt water and gas.
Do	Coal Company		498	500	
Gordon, 4 miles north.					Flow of salt water and gas.
Strawn		900			Flowing salt water and gas.
Parker County:					

Springtown. Six or seven flowing wells, 75 to 100 feet deep, costing $50 to $100 each.

Dalton's	J. F. Johnson				

Refugio County.—Refugio. Three flowing wells with joint capacity of 500,000 gallons per diem. Two wells belonging to O'Connor Brothers are reported at depths of 853 and 956 feet, with a combined flow of about 300,000 gallons daily, rising 48 and 54 feet, respectively, above surface.

Robertson County.—Large number of flowing wells in this county.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Dimmit County:					
Carrizo Springs			175		4-inch stream.
Somervell County:					
Glen Rose P. O.	George Abel		260	325	40 gallons per minute.
Do	W. M. Lanham				
	Dr. Scott Milam; well near Walnut Springs station, Texas Central Railroad.		79	100	10 gallons per minute, water pure; used for domestic, stock, and ½-acre garden.
	Rev. O. M. Addison; well west side Brazos River, near Bosque County line.		337	500	10 gallons per minute; well bored in 1885. Water sweet, pure, and soft. Uses, domestic, stock, etc., and ½-acre garden; good effect.

Dr. Scott Milam reports about 200 artesian wells within 10 miles of Glen Rose. Range in depth from 70 to 350 feet. Flow from 2 to 200 gallons per minute. Cost, generally, 75 cents per foot first 100 feet, with 25 cents per foot increase for each additional 100 feet. Water used generally for domestic, stock, etc., purposes. Some gardens irrigated with good effect. If means of irrigation provided land would double in value.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
Stephens County:					
Wayland	Frank Maxwell		175		Flows a strong stream.
Do	S. C. Ellis		100		Do.
Do	Squire Hodges		120		About 8 gallons per minute.
Do	Wm. Sadderthwaite		120		Do.
Do	J. F. Ford		150		All have good flowing wells, 100 to 180 feet deep, costing from $50 to $200.
Do	J. S. Little		150		
Do	J. D. Rhea				
Do	W. F. Fambraugh		156	*150	9 gallons per minute.
Tarrant County:					
Fort Worth	J. T. Smith	629	211		30 gallons per minute.
Do	A. J. Chambers		266		40 gallons per minute.
Do	W. T. Boaz		300		30 gallons per minute.
Do	Frank Ellison		450		Ceased flowing.
Do	L. W. Crawford		465		10 gallons per minute.
Do	Fort Worth Ice Company.		360		70 gallons; ceased flowing.
Do	E. B. Daggett		300		70 gallons per minute.
Do	R. E. Maddax		320		50 gallons per minute.
Do	Town Council		950		140 gallons per minute.
Do	Texas and Pacific Railway.		450		Small stream.
Do	do		760		Do.

In this county, one flowing well, 7 miles south of Fort Worth, said to be the strongest flow in the county. Two flowing wells on Schoonover survey, one on Bauer survey, one on Watson survey, one on James Rightly survey, one on Harry Robinson survey, one on M. and E. P. R. R. survey, one on G. B. Stanley survey, one on Van Norstrand survey, varying in depth from 400 to 500 feet.

*With tubing and casing.

Modern flowing wells—Continued.

County and post office.	Owner or informant.	Altitude.	Depth.	Cost.	Flow per minute, etc.
		Feet.	*Feet.*		
Handley Station	Fishing club				4½ inch flow keeps large lake full of water.
Uvalde County:					
Utopia	H. S. Donoho	891	200		
Do	do		200		
Two other wells reported in county; depth, 102 and 110 feet. Cost of former $125; 6-inch bore. Flow 3½ gallons per minute; latter well not continous. Flows at 15 gallons, or stops entirely.					
Webb County:					
Laredo	Electric Light Company.		335		Small flow, unfit for use.
Cactus	G. Huerta		170	450	3 gallons per minute.
Laredo	Q. Brune		75		Small flow mineral water.
Williamson County:					
Taylor	Citzens		1,500		Above ground, warm water, 4-inch stream, rises 40 feet.
			370		15 gallons per minute.
			313		Do.
Llano County:					
Packsaddle	W. E. Rabb		200		
Robertson County:					
Calvert		337			
Two flowing wells of small capacity in this town.					
Gonzales County:					
Rancho post-office	Dr. J. K. P. Green	276	130	400	3 gallons per minute.
	Jas. M. York		192		3½ gallons per minute.
	Jasper Been		216		5 gallons per minute.
Dimmit County:					
Carrizo Springs	S. D. Frazier		165	330	40 gallons per minute.
	Dr. M. W. C. Frazier				Said to own flowing wells. No information in time for report.
	H. W. Peters				
	John Pfeiffer				
	W. C. Dickens				

Artesian wells under construction or contract.

Location.	Altitude.	Remarks.
	Feet.	
Waco, McLennan County		Bell Water Company (8-inch bore).
City of El Paso, El Paso County.	3,713	Contract let to bore an artesian well; $28,000 appropriated for this purpose.
Corsicana, Navarro County	448	Artesian well for city waterworks.
Round Rock, Williamson County.	720	Do.
Abilene, Taylor County	1,700	Artesian well for city waterworks; appropriation for this purpose $15,000; contractors to bore 2,500 feet, if necessary.
Dallas, Dallas County	466	County and city let contract for artesian well; contractors to bore 2,500 feet, if necessary.
Belton, Bell County	620	Contract let for artesian well for city waterworks.
Goldthwaite, Mills County		Artesian well down 563 feet, and water within 20 feet of the top; well is 10 inches at top and 7 inches at the bottom; a second well at 600 feet, with flow, was struck June 9, 1890.
Corpus Christi, Nueces County.	20	Artesian well now being bored.
Fort Worth, Tarrant County.	629	City waterworks, Tucker's Hill well, down 950 feet; flow, 140 gallons per minute; work to be continued until a flow of 500,000 gallons per diem is secured.
Webb County		Laredo Improvement Co.; down 900 feet, and continuing the work.
Toyah, Reeves County	2,975	Texas and Pacific artesian well; down 300 feet, and will continue to 1,000 feet.
Austin, Travis County	513	State Lunatic Asylum well 1,280 feet deep; a flow secured and work about to be discontinued.
Kerr County		Charles Schreiner, at Kerrville, is boring an artesian well.
Grayson County	747	Sherman city water supply; boring 12-inch hole to a depth of 1,000 feet.
Cleburne, Johnson County	933	Citizens boring artesian well down over 600 feet and continuing.
Vernon, Wilbarger County		An artesian well is to be bored by the local Waterworks Company.
Thurber, Erath County		Texas and Pacific Coal Company have reached a depth of 958 feet, getting a small flow of salt and sulphur water; the boring is being carried farther down.

Artesian well failures.

Location.	Altitude.	Remarks
	Feet.	
Colorado City artesian well, Mitchell County.	2,075	Bored 1,120 feet, struck salt water; never secured a flow; now used in salt works.
Weatherford, Parker County	870	Schoolhouse well bored 500 feet; water 50 feet from surface; mouth of well 945 feet above sea level.
Breckinridge, Stephens County.	....	Bored 1,400 feet, but got no water; appropriation gave out and well abandoned.
Eastland, Eastland County ..	1,299	One bored 500 feet; tools wedged in the hole and work discontinued. Second well: 6-inch bore, 1,300 feet; salt water and no flow. The two wells were bored in 1882 and cost the owner, Hy. Eversole, $3,500. Altitude of Eastland 1,610 feet above sea level. Cisco artesian well, bored 8-inch hole to a depth of 1,680 feet; water within 25 feet of the top; salt water and work discontinued; cost between $3,500 and $4,000; altitude at Cisco 1,690 feet.
Big Spring, Howard County.	2,400	7-inch artesian well; depth 603 feet; salt water for 300 feet, then fresh water; no flow; appropriation $5,000 expended, and work abandoned.
Lanham, Hamilton County ..	....	One well bored 470 and another 500 feet; in both a layer of material was encountered that made it impossible to proceed with the work, which was abandoned.
Odessa, Ector County	2,900	Bored an 8-inch well 830 feet; casing was telescoped and well clogged; well abandoned.
Midland, Midland County....	2,780	Artesian well bored about 350 feet; no flow; appropriation gave out and work discontinued.
Corpus Christi, Nueces County.	20	Bored 1,700 feet; sulphur and salt water.
Honido City, Medina County.	....	Southern Pacific Railroad; bored 1,000 feet and no water.
Finlay, El Paso County......	3,945	Southern Pacific Railroad. Altitude 3,945. Bored 1,080 feet, 8-inch hole at bottom. Very bad water at 396 feet. No flow. Well abandoned.
Sierra Blanco................	4,512	Bored 943 feet, 5⅝ diameter at mouth and bottom. Unlimited supply of poor water, but no flow. Deep well walking pump, capacity 1,890 gallons per hour.
Torbert.....................	4,343	Bored 1,100 feet, mouth 8 inches, bottom 5⅝ inches. Small stream of fair water at 696 feet. No flow. Well abandoned.
City of El Paso..............	3,713	One well bored on mountain side northwest from El Paso, in granite, to a depth of over 800 feet. No water secured.
San Antonio, Bexar County..	683	F. M. Rowe. Bored 500 feet; no good water. Water at 225 feet, and oil at 350; cased off both at 360 feet, and had a dry hole at 500. Well abandoned.
Hillsboro, Hill County.......	....	Bored 500 feet. No flow. Abandoned.
Hardeman County...........	....	New York Copper Company. Bored 1,200 feet. No flowing water in 1884. Well abandoned.
Cleburne, Johnson County...	933	Bored 4 wells of 360 feet each but got no flow. Are now at work on a new one.
Brown County...............	....	F. M. Kitchens, Menardville. Messrs. Coggins Bros., Brownwood, bored for artesian water. Struck sour water at 150 feet, oil and salt water at 450 feet, after that fresher water. Had the well been thoroughly cased at 800 feet it would have been a success. They went 1,100 feet, and well failed.
Laredo, Webb County.......	....	The Mexican National Railway have made repeated efforts to drill wells, but have failed.
Henrietta, Wilbarger County	915	On block 13, a bored well 320 feet deep with salty water.
Graham, Young County......	900	Corbondale; a prospect hole, 300 feet deep, cost $325. No flow. But salt water at 80 to 150 feet.
Bremond, Robertson County	467	Artesian well bored 1,500 feet through alternate layers of clay and blue muck. No flow secured, though there is water in the well.
Waco, McLennan County ...	....	Four or five wells have been bored here to a depth of 200 to 1,600 feet, all of which were abandoned because the tools became lodged and could not be removed.
Baird, Callahan County	1,524	Texas and Pacific Railway; well bored 8 inches, 415 feet, at a cost of $900; drill stuck fast in well; abandoned.
Cisco, Eastland County	1,611	Railroad well bored 265 feet; struck soda water and quit.
Paris, Lamar County	592	City waterworks bored 444 feet; stopped in non-water-bearing soapstone; well abandoned.
Brenham, Washington County.	301	Bored 600 feet; broke down and quit.

The unsuccessful attempts to find artesian water probably run high into the hundreds, but information concerning them is difficult to obtain. The necessity of having such wells is fully appreciated, but as a rule just enough money is raised as will be necessary to insure a failure.

It appears that within District No. 1 there are between 600 and 675 flowing wells, varying in flow from 1 gallon per minute to 973 gallons per minute; varying in depth from 15 feet to 1,834 feet, and in cost from $15 to $7,200.

NEGATIVE ARTESIAN WELLS.

In accordance with the definition of "artesian waters," as accepted by the artesian wells investigation, to wit:

To include all subterranean waters which, on being reached or opened from above, are found to flow to a level higher than the point of contact. Another consideration is that the said waters shall flow from some permanent and general source, rather than from a local and temporary one. All bored wells in which the water rises, though not above the surface, may be included in the term artesian. Also all natural waters, such as springs, rising from below, are embraced in this definition.

The number of wells of this class runs high into the thousands, and such occur in nearly every county of the State. Practical well drillers as a rule regard the rising of water in the bored wells as a certain indication that flowing water can be obtained if the boring is carried down deep enough.

Location.	Owner.	Altitude.	Total depth.	Water lines (feet from surface).	Pumping yield per minute.	Remarks.
Archer County:		Feet.	Feet.		Gallons.	
Archer City	Town Company		500	30		Salt water.
			201	(*)		Good for drinking.
Bexar County: Bulverde P. O.	R. Mecke	1,600	365			Water rose 250 feet in well; used for stock.
Comanche County: Comanche, 7 miles west.	St. John survey		60	10		Not now in use.
Frio County	Hy. Maney					There are many wells bored in Frio County in which the water has risen 100 or more feet. In dug wells, 25 to 70 feet, the water rises often above the point where found.
Grayson County: Sherman	Texas and Pacific Railway.	747	632			
	Sherman Ice Co		915			
Grimes County: Navasota	E. L. Bridge	219	250	11	†100,000	Excellent water rose to the surface.
			830	11		
Hill County; Files P. O	J. O. Files					Large number of non-flowing bored wells yielding great quantities of water. One well at this place 250 feet deep has 150 feet of water.
Jack County: Jackboro and Center Point P. O.		1,133				Wells from 60 to 200 feet deep. Water rises but not to surface; supply lasting. Cost $1 to $1.50 per foot.
Johnson County: Equestria	Jas. Drennan	‡953				Town of Cleburne has bored four wells to a depth of 360 feet, no flow. Water rose 200 feet in each of the wells.

* Water rose 10 feet. † In 24 hours. ‡ At Cleburne.

Location.	Owner.	Altitude.	Total depth.	Water lines (feet from surface).	Pumping yield per minute.	Remarks.
		Feet.	*Feet.*		*Gallons.*	
Jones County: Phantom Hill	Thos. F. Scott	2,300	......	......	......	Most bored wells are from 60 to 100 feet deep. The water often rises from 20 to 40 feet higher than where first found.
Taylor County: Merkel P. O.	J. L. Vaughan	1,875	......	......	......	A majority of the wells are dug, a few bored. Depth from 25 to 75 feet. Water rises from 10 to 25 feet until it runs off in a porous stratum of sand. Excellent, soft water.
Do	Hill and Tracy	......	56	......	*10,000	Good.
Do	W. J. Slaton	......	32	15	......	Do.
Parker County: Weatherford	City water supply	870	402	250	*100,000	Do.
Robertson County: Calvert	......	337	288	30	†100	Do.
Stephens County	N. S. Greenwood	......	600	15	......	The stream entering near surface rendered well water unfit for use.
Tarrant County: Fort Worth	......	629	......	......	......	There are in the city of Fort Worth 242 artesian wells, of which only three are *now* said to be flowing. A majority of these wells did flow originally, and all them rise in the wells. A great number of steam pumps are used, drawing from 50 to 100 gallons per minute. Some of the low-lying wells rise a number of feet during each night, but lower during the day.
Taylor County: Merkel	J. L. Vaughan	1,875	74	25	*30,000	Lime in water. Fifty-eight feet of this well are dug 10 feet square. In bottom there are drill holes, out of which a strong flow.
Wise County: Rhome	J. Y. Hoggsett	......	198	50	......	Abundant, very, soft water.
Ellis County	John Chamblee	......	268	20	......	Alkaline; worthless.
Do	A. W. Tucker	......	286	30	......	Useless; soda, etc.
Tarrant County	John A. Wims, Fort Worth.	......	484	50	†50	Good water.
Do	Town of Keller	......	457	50	†50	Do.
Do	R. H. King, Fort Worth.	......	263	30	......	Abundant and good.

Young County, Farmer post-office; C. Pettit, owner; altitude, 2,250 feet; depth, 132 feet; (data not given). Water, salt. (Reports two other bored wells, at 182 and 240 feet, but gives no data.)

*Daily. †Per minute.

There are thousands of artesian wells that do not overflow in district No. 1, but a record of them has not been secured. It is safe to say that such can be had in any of the counties by boring from 100 to 500 feet, and a majority will supply 50 to 100 gallons per minute at a much less depth.

Stratification of flowing and deep wells in the several counties of Texas, in District No. 1.

Archer County, Archer City.—Not flowing.

	Feet.
Red clay	25
Sand rock	10
Red clay and hardpan	500
Black soil	5
Light red clays	30
Cap rock	½
Red clay	100
White rock	10
Sand rock	14
Soft white rock	7
Red clay	5
Sand rock	6
Soapstone	11
Water gravel	1
Sand rock	12
Water (does not overflow).	

Atascosa County, Pleasanton.—Altitude 75 or 100 feet above Pearsall. Blue marl or soapstone, with occasional strata of sand or rock down to water. Went 175 feet below this, but found no more water. This is not strictly a flowing well. Water rose within 10 feet of surface. A syphon pipe inserted flows 10 gallons per minute.

Bexar County, San Antonio.—Crystal Ice Company. (Altitude, 683.)

	Feet.
Black alluvial	4
Impervious yellow clay	12
Gravel	20
Blue clay	300
Soapstone	250
Black mud	60
Very hard sand stone	5

A 40-foot, 8-inch drive pipe; sulphur water and gas at 375 feet, about 25 gallons per minute. Reduced bore to 5⅝-inch at 600 feet. At 650 feet very strong flow of soft water. Pressure, 40 pounds.

Bexar County, Bulverde post office.—R. Mecke well. (Altitude, 1,600 feet.) Depth, 365 feet. Water rises 250 feet in well; used for stock. Reported by O. Vogel, Bulverde post office.

	Feet.
Soft yellow stone	42
Blue stone	20
Yellow stone	18
Blue stone	2
Yellow stone	6
Blue limestone	19
White limestone (struck water)	30
Blue sandrock	10
Blue slate	40
Red clay	13
Limestone	60
Sandstone	31
Sand quartz	1
Yellow clay	23
Limestone	35
Sandstone (strong supply of water rises 250 feet in well)	11
	361

Bexar County, San Antonio.—Banes' well. (Altitude 683.)

	Feet.
Gravel	8
Yellow clay	50
Blue clay	175
Slush and mud, sometimes lighter, sometimes darker	262
More like slate	5
	500

Water at 225; oil at 250 feet; about 4 barrels of water per day, at 350 feet; 50 gallons of oil per day. At this depth, 250 feet of water in well.

Wood casing, 8 feet; 224 feet, 5⅝-inch casing; at 230 feet put in 4-inch drive pipe; at 360 feet shut off all water and oil; left a dry hole at 500 feet.

NOTE.—North of San Antonio for the next 150 miles the drilling very hard and bad, much flint; but all the prairie country is good; get plenty of water at from 300 to 500 feet.

One well, 4 miles south of San Antonio, 675 feet, all soft material except the last 70 feet, which was very hard white sandstone.—F. M. Rowe, San Antonio.

Bexar County, San Antonio.—West End Town Company Wells. Depth, 260 feet. (Altitude, 650 feet.) Flow, 150 gallons per minute.

	Feet.
Black alluvial soil	5
Impervious yellow clay	10
Coarse gravel	10

Balance soft blue rock impregnated with petroleum. Water strata about 9 feet thick, apparently an underground stream, the bed of which is covered with a red or dark yellow clay, mixed with decomposed shell. No water until we reached 260 feet.

I am satisfied artesian water can be had in many portions of southwest Texas at small cost, and will treble, at least, the value of land.—Geo. W. Russ, President W. E. Town Co.

Bosque County, Meridian. (Altitude 791 feet). Dr. J. J. Lumpkin's well. White beach sand brought from bottom of well, 500 feet. Water will flow 50 feet above ground.

	Feet.
Soil	10
Lime rock	300
Beach sand	28

Balance is mud, marl, and green clay. No change in flow. Diminished in another well.

Town well. Increase in flow; 24 gallons per minute.

Bosque County, Iredell. (Altitude, 881 feet). Same altitude as railroad track. Public well; 28 gallons per minute. Diminished one-third, caused by casing.

	Feet.
Soil	20
Limestone	10
Blue soft rock	80
Blue marl	6
Soft white stone	50
Sandstone, limestone, marl	100
Soft sand rock	} 45
Hard sand rock	}
Granite or emery stone	6
Flow of water and pack sand	18
	345

Bosque County, Kopperl post office.—Three wells, 525,800, and 600 feet deep, throw up small amount of white sand. Have neither increased or diminished. (Altitude, 574 feet.)

Bosque County, Eulogy post office.—Struck water at 30 feet; began to flow at 450 feet; increased flow at 480 feet. Water soft and clear, almost free from mineral. No change in flow.

Bosque County, Morgan post office. (Altitude about 734 feet). Depth of well, 550 feet. Muirhead W. Co. Flow 20 gallons per minute; will rise 45 feet above ground.

Burnet County, Oakalla.—J. M. Kincaid's well. Altitude same as Copperas Cove.

	Feet.
Black alluvial	12
Yellow clay	8
Blue limestone	76
	96

Sand, gravel, and water. Flow about 50 gallons per hour No change in flow.

Coleman County, Trickham.—Well 220 feet; flows salt water and oil. Black and gray sandstone (10 feet) mixed with clay the balance.

Coryell County, Pidcock Ranch.—Altitude of well about same as Copperas Cove.

	Feet.
Black alluvial soil	3
Blue limestone	219
Sandstone	30

Struck flowing water at 243 feet; and a small quantity at 163 feet. Used 5⅝-inch casing 35 feet from surface. No change in flow.

Coryell County, King P. O.—Altitude about same as at Gatesville.

Solid lime rock, 240 feet; flow, 2 gallons per minute and no change.

Coryell County, Pecan Grove.—Davidson well. Altitude same as Leon Junction, Cottonbelt Railroad. Depth, 220 feet.

	Feet.
Black land	3
Sand rock	12

Balance rock in layers of 18 to 20 feet.

Coryell County.—W. H. Belcher well, Cowhouse Valley. Altitude about 2,500 feet. Depth, 290 feet. Flow, 2½ gallons per minute. No change.

	Feet.
Sand and gravel	25
Limestone	150
Porous sandstone	2
Limestone (water seeping)	100
Sandstone	13
	290

Water used for domestic purposes, stock, etc. Small garden irrigated; effect very good.

De Witt County, Yorktown.—Eckhart's well (altitude 177 at Cuero.)

	Feet.
Clay and sand	18
Joint and fire clay	46

Water in sand.—Flow, 7 to 8 gallons per minute and no change. Total depth, 64 feet.

Denton County, Denton P. O.—Refrigerator and Canning Company well. Depth, about 550 feet. Flow, 5 to 8 gallons per minute. Temperature of water at mouth of well about 72° F.

	Feet.
Top soil to rock	20
Rock to depth of 518 feet, when water rose to within 20 feet of top	518

Heavy mud, hard stone, sand bed (with flowing water) 15 feet thick.

Water soft and clear. Three other wells in town, with about same depth, quality of water, and flow. Reported by J. C. Coit.

Erath, Somerville, Hood, and Bosque Counties.

	Feet.
Top soil sandy loam	10 to 20
White pack sand	25 to 100
Gravel	1 to 5
Red clay or coal	10 to 25
Artesian sand	25
Red clay or coal	10
Blue marl	10

Slate, mixed. Flow in different wells from 20 to 200 gallons per minute. Pressure from 10 to 50 pounds. Depth of wells range from 150 to 800 feet. Some have increased in flow and others have diminished.

Frio County, Pearsall.—T. A. and J. W. De Vilbiss' wells. Altitude 50 feet below track at Pearsall. Depth of wells, 158, 260, 391 feet.

Sandstone	30
Blue marl, hard blue rock	128

Flow, 3½ to 8½ gallons per minute. Blue sand brought up. Slightly increased in flow.

Goliad County, Goliad (altitude 50 feet).—Judge Shaper's wells flow each 10 gallons per minute of pure water. Each 60 feet deep and increased in flow. Yellow and red clay 60 feet.

Grayson County, Pottsborough (altitude, 722 feet).—Brennan & Paxton well; bored for coal. Flow estimated at 250,000 gallons per twenty-four hours, which seems to have increased. Depth, 250 feet; brings up grayish-white material. Pressure estimated at 10 pounds.

	Feet.
Soil	10
Soapstone, the balance	240

Grimes County, Navasota (altitude, 219).—E. L. Bridge's well.

	Feet.
Black soil	6
Joint clay	10
Sandstone	16
Potters' clay	9
Quicksand	80
Sandstone	10
Sand	8
Gravel	12
Gravel and clay	14
Sandstone	10
Clay and black———	15
Sandstone and sand	120

Total depth, 830 feet. Found water that rose to within 11 feet of the surface at 250 feet. At 830 found water, potable, that rises to the surface of the well. Temperature, 80°.

Hardeman County.—Average well in county:

	Feet.
Chocolate surface soil	3
Calcareous gravel	10
Blue clay	3
Gypsum	40

Hill County, Files Valley (altitude about 460 feet).—J. R. Lane's well. Flow, 3 gallons per minute, supporting column of 20 feet. Depth, 123 feet.

	Feet.
Black alluvial	4
Yellow clay	16
Coarse gravel	10
Slate with hard rock above artesian water in sandstone 3 or 4 feet thick	93
	123

Water is clear and soft, and has not changed in quantity.

Jack County, Jacksborough (altitude, 1,133).—Centerpoint wells, 96 to 130 feet deep; flow continuously, without any change in quantity.

McCulloch County, Waldrip.—Two wells bored by coal prospectors; depth, 110 feet and 220 feet. Diameter of bore, 2 by 2¾ inches. Water salty and oily. One of the wells on bank of Colorado River. Limestone shales and 1 foot of coal 110 feet. The other well is about 4 miles south of No. 1.

	Feet.
Soil	10
Sand rock, shales, and blue clay	210
	220

McLennan County, Waco.—J. J. More well. Depth, 1,852 feet; flow, 500,000 gallons in twenty-four hours. Pressure 60 pounds to the square inch; cost, $6,500. First 1,500 feet, at $2 per foot; next 100, $3 per foot; next 100 $4 per foot; next 100 feet, $5 per foot. Small increase in flow. Temperature of water 103°. Very soft and clear.

	Feet.
Soil	20
Soft or rotten limestone	1,250
Harder limestone, dark color	450
Gray limestone, very hard and very fine texture	100
White porous sand rock, containing the artesian water	32
	1,852

This well was dry for 1,000 feet, then small stream of sulphur water; after this several small streams, which flowed over top of well, very strong with sulphur, salt, and iron. Very little more found until 1,820 feet, when a porous white sand rock was struck, which yields the water. This is one of the city waterworks wells. The pressure from this and the other wells belonging to the waterworks is sufficient to cause an 80-foot standpipe to overflow.

Maverick County, Eagle Pass (altitude 800 feet).—Fitch's well, still under construction.

	Feet.
Brown alluvial soil	14
Yellow clay	26
Soapstone	50
Sand and shale	110
Black shale	60
Sand and clay, mixed	70
Gray sand	30
Salt water	
Sand and shale	60
Sand, pure	20
Gray shale	30
Dark shale and salt water	55
Coal, very fine quality	6
Shale	9
Sand, strong flow of gas	40
Black shale	150
Sand and shale	15
Black shale	135
Sand and shale	15
Dark soft sand and shale	75
Hard gray sandstone	108
Black shale	65
	1,140

The drill is still working in this stratum. The flow of salt water is not very strong. The well is cased to its present depth.

Montague County, Sunset.—Common wells; sand, red clay, clay and pack sand, quicksand, gravel, and water.

Palo Pinto County, Gordon (altitude, 875 feet).—Two wells, 485 and 498 feet deep; flow, 1 gallon salt water per minute. No change in flow. Pressure about 10 pounds. Inflammable gas issues from both wells.

Parker County, Weatherford (altitude, 870 feet).—Weatherford Water, Light and Ice Company; dug well 30 feet; balance bored.

	Feet.
Soil	10
Clay	18
Pack sand	20
Shales and limestones	400
Gravel and sand	6
Red clay	34

Struck water at 402; does not flow, but comes within 250 feet of the surface. This well will be bored deeper.

Robertson County, Calvert (altitude, 337 feet).—Water, Ice and Electric Light Company.

	Feet.
Sand and clay to	54
Clay to	60
Coal	8
Blue clay	22
Sand and gravel	18
Sand clay	8
Rotten rock	2
Sand, gravel, and water at	288

Water rises to within 30 feet of top and pumps 100 gallons per minute.

Refugio County.—O'Connor Bro.'s wells. No. 1: Located about 5 miles south San Antonio River; altitude, about 60 feet; depth, 956 feet; 5-inch casing; flow, about 100,000 gallons daily; rises 54 feet above surface; used for stock; water soft and clear.

	Feet.
Black alluvial soil	9
Yellow clay and sand	91
Rock	8
White dobie clay	638
Hard red clay	200
Water strata (in flint gravel)	10
	956

Water struck at 946 feet.

Well No. 2: Located about 6 miles southwest of No. 1. Altitude, about 65 feet above tide water; depth, 853 feet; rises in tube 48 feet above surface. Fine water for all purposes. The flow from this well is about double that of No. 1; 8-inch casing.

	Feet.
Black alluvial soil	9
Yellow clay	273
Rock	4
Yellow clay	522
Sand (very fine)	18
Water strata	27
	853

Cost about $4,000 each. Another well being bored.

Somervell County, Glen Rose.—George Abel's well. Two hundred and sixty feet deep. No casing. Runs out like a spring. Flow, 40 gallons a minute, and has not changed.

	Feet.
Sand soil	2
Impervious yellow clay	8
Rock and marl	240
Coarse sand	10
	260

Bore 6 inches.

Struck bed rock at 10 feet. Well flowed at 200 feet. Water soft and clear; slight chalky taste.

Addison well, west side of Brazos River, near Bosque County line. Flows 10 gallons per minute; continuous; bored in 1885. When pipe was placed in well, water flowed to height of 20 feet above surface.

	Feet.
Sandy loam	1
Coarse gravel	20
Blue limestone	266
Sand	10

Water used for domestic, stock, and one-half acre for garden purposes. "The water is pure, sweet, and softer than rain water, rather cooler than ordinary artesian water."—Oscar M. Addison.

Well near Walnut Springs Station, Texas Central Railroad. Reported by Dr. Scott Milam, of Glen Rose. Depth, 79 feet; flow, 10 gallons per minute. Cost about $100. Water soft; used for domestic purposes; also on garden of one-half acre.

	Feet.
Earth, sand, and clay	12
Hard limestone	62
White sand	7
Total depth	81

Stephens County, Wayland.—No flowing wells in county except within radius of 2 miles from Wayland. Flow 3 to 10 gallons per minute, and apparently no change in flow.

Blue slate, yellow sand, and coarse, white sand and gravel; hard, white sand; red sandstone; hard, blue limestone.

Fambrough well: Depth, 156 feet; flow, 9 gallons per minute; cost, $150.

	Feet
Clay	30
Limestone	5
Soapstone	20
Slatestone	15
Soft sandstone	86
	156

Water for domestic and farm uses; irrigated a three-fourths acre garden with very good effect.

Taylor County, Merkel (altitude, 1,875 feet).—Railroad well, the deepest in vicinity.

	Feet.
Chocolate-colored alluvial	5
Coarse gravel	9
Fine sand and gravel	1
Coarse gravel	9
Carboniferous sandstone	30
Hard red and white rock	1
Porous rock, with water pockets	1
Red sandstone, with caverns	18

The water contains some lime, but becomes soft on exposure to air and sunshine. In drilling the tool would frequently drop down several inches in caverns, followed in each case by an increased flow of water.—J. L. Vaughan.

Uvalde County.—Two wells reported. Depth, 102 and 110 feet; 6-inch bore; former flows at $3\frac{1}{2}$ gallons per minute; latter at 15 gallons or stops entirely; water somewhat mineral, but good to drink for man and beast; strata reported, "after 16 feet of gravel, solid rock."

Wise County, Rhome.—J. T. Hoggsett, Fort Worth, owner.

	Feet.
Black waxy soil	5
Limestone	145
Pack sand	50
	200

Water rises within 50 feet of the top; comes from a clear white sand rock (pack sand?) in a very strong stream. A $5\frac{1}{2}$-inch cylinder, with windmill, cannot exhaust the well.

Webb County, Cactus.—G. Huerta's well. Altitude, 75 feet below railroad track at Cactus. Depth, 170 feet: flow, 3 gallons per minute without change.

Sand rock, impervious yellow clay, blue limestone, whitish sandstone, gravel.

Parker County, Weatherford (altitude, 870 feet).—In ordinary wells, 30 to 60 feet.

Soil, white pack sand, clay, and sand.

Water works well.

Palo Pinto County, Gordon (altitude, railroad, 875 feet; barometer, 1,130 feet).—Three flowing wells.

Soil, sandstone, slate rock or hard blue clay, purple joint clay.

Very salty water at 200 feet; flowing water in white sand, 488 feet.

There is a probability that the last water is fresh, but as the well has no casing this can not be determined. Gas with bright flame comes up with the water. Pressure in 5-inch wooden pipe about 12 to 15 pounds. All common dug wells in town have salt water.

Santo Station, Palo Pinto County.—Two bored wells, 50 and 100 feet; both have mineral water of bad quality.

Eastland County, Eastland (altitude, 1,299 feet).—Two bored wells, both failures, and have salt water. One at 500 feet, the other 1,300 feet.

Soil, sandstone, 12 to 15 feet; coal, sandstone, slate, coal.

Gray marble at 600 feet; in well No. 1, water at 60 feet; in well No. 2, water at 120 feet.

A number of salt-water deposits to a depth of 600 feet. Below this, water that came within 12 feet of the surface. The water, boiled down, leaves a residue of salt. It is thought that the last deposit was pure water. Salt water is found near Eastland in common wells from 20 to 70 feet.

Dallas County, Dallas City (altitude, 466 feet).—Well of J. J. Brick. Flow 12 gallons per minute, with pressure of about 30 pounds. By pumping, furnishes 100 gallons per minute.

	Feet.
Soil	2
Blue mud and soft rock	50
Soft white rock	20
Black rock	50
Gray rock	150
Various colors each	50
Water in white sand rock	10

Fossils, coal, flint found in several strata. Used in a bath house. Owner thinks a strong flow would be secured at 1,500 feet.

Ellis County, Midlothian.—A. W. Tucker's well. Depth, 286 feet; diameter, 8 inches.

	Feet.
Soil	4
Soft white magnesia limestone	20
Blue soft limestone	234
Light yellow colored sandstone and sand	20

At 50 feet small quantity of water. At 286 feet strong flow to within 30 feet of surface.

Color of water somewhat milky; flavor like soda, with bitter after-taste. Purgative. Soft, and used for washing clothes.

Eastland County, Cisco (altitude, 1,625 feet).—Eight-inch well; depth, 1,680 feet; top soil, black; blue clay, 100 feet.

Then alternate layers of white and yellow sand and layers of clay. First water, at 60 feet, hard lime water; at 100 feet, good water that could be pumped, small quantity; small veins to 1,000 feet, when a large supply of good water was struck that rose within 25 feet of the top. Only one layer of water below this. None of the water is bad. The last strata encountered was sand rock, and it is the opinion of the borers, McLeese & Swan, that a flow would have been secured if this strata had been bored through. Barometer at Cisco, 1,690 feet.

McLennan County, Waco.—Bell waterworks flowing wells. Altitude, 80 feet above railroad track at Waco; top soil, 12 feet.

White limestone alternating with blue soapstone or shale to a depth of 1,100 feet. The intermediate shales more or less soft. At 1,150 feet hard blue limestone to a depth of about 1,800, then a gray sandstone, changing to white, 20 to 25 feet thick, then 12 to 20 feet blue slate mixed with sand and flowing water, passing on into yellow clay.

In one of the wells, at about 500 feet, a few lime bowlders as large as goose eggs. At 1,800 feet, in one well, red clay 15 feet thick lying on sand.

Shells found in all the strata penetrated.

In an old well, bored 720 feet, a seepage of oil at 100 to 200 feet. Another well, only 20 feet distant from the foregoing, passed through 500 feet of shales without encountering rock of any kind.

A very weak stream of water rising to the surface is usually found at a depth of 1,100 feet.

In the blue slate in which the great flow is found there seem to be numerous crevices, caverns, etc., out of which the water is forced at great pressure.

The water of all the artesian wells of Waco is identical as to chemical analysis, and has a temperature of 102 degrees as it issues from the well.

Johnson County, Cleburne (altitude, 933 feet).—Soil, limestone magnesian, 40 feet; gray sandstone alternating with slate, 900 feet; blue shales, quicksand.

No flow at this writing, the work of boring being continued.

Robertson County, Bremond (altitude, 467 feet).—Artesian well boring 1,500 feet, resulting in failure. Entire boring through alternate layers of clay and blue muck. No flow secured.

Bosque County, Morgan.—Muirhead and White's wells (altitude, 734 feet).

Top soil, black hog wallow, 15 feet; sand and clay or red joint clay sand, 1 or 2 inches; shell lime rock, 5 or 6 feet.

Water in gravel, sand, and clay; blue lime rock with shells and iron, 1 or 2 feet; 8 to 15 inches iron pyrites, alternating layers of clay, white rock, soft limestone, blue hard limestone to a depth of 500 feet; then heavy quicksand.

Artesian water in white pack sand, 68 feet thick; generally found at a depth of 540 to 560 feet.

The same strata in west part of Bosque County at 250 feet.

From 50 to 75 feet below this, stone and quicksand, and a second layer of artesian water.

The third layer of artesian water is from 50 to 75 feet below the second layer. Up to date three distinct sources of artesian water have been found. All the wells in the valley of the Bosque have a depth of 250 to 300 feet, and the average flow is about 30 gallons per minute, though most of them flow from 15 to 20 gallons. A limited few have only a flow of 5 to 10 gallons, but a number of others flow over 100 gallons per minute.

It is generally accepted that the first strata will furnish from a 4-inch hole 15 to 20 gallons per minute, from the second stratum 30 to 50 gallons, and from the third 75 to 100 and more per minute.

Bosque County, Morgan (altitude, 734 feet).—J. S. Stroud, well borer, reports stratification of the average Bosque County artesian well as follows: Top soil, 10 to 20 feet; blue limestone, 20 to 60 feet; drills easily and carries fossils.

Sand, with water at 80 to 100 feet; hard blue sandstone, 6 to 8 inches, very hard to drill.

White limestone with fossils, about 400 feet of aforesaid fossil limestone alternating with layers of 1 to 1½ feet of blue joint clay.

Dark green clay 1 foot thick in two layers 6 feet apart and absolutely waterproof. Artesian water in yellow sand. Though the wall stands it is neither pack sand or sandstone. The artesian layer is usually found at 540 to 560 feet.

Somervell County.—J. S. Stroud, well borer, Morgan, Tex.; artesian layer at 100 to 300 feet.

Erath County.—J. S. Stroud. Artesian layer at 450 feet.

Hood County.—J. S. Stroud. Artesian layer at 300 feet in two wells.

Clay County, Henrietta (altitude, 915 feet).—Average common well. Jas. F. Carter. Soil sandy loam, sandstone from 6 to 25 feet.

Tarrant County, Fort Worth (altitude, 629 feet).—John A. Wims's well, 5 miles southeast, 6-inch bore.

	Feet.
Yellow clay	30
Blue soapstone	2
White lime rock	49
Blue soapstone	24
White lime rock	40
Brown soapstone	20
Very hard shell rock	2
Brown soapstone, with hard streaks	28
White limestone	95
Blue soapstone	42
White limestone	52
Blue soapstone	5
White limestone	34
Blue soapstone	5
White limestone	5
Blue soapstone	7
Shell rock	22
Brown sand rock	13
White sand rock	14

Depth of well, 484 feet. Cost, $484. No casing. Water rises to 50 feet from surface, and will stand pumping 50 gallons per minute.—G. B. Morgan.

Tarrant County, Keller.—Six-inch bore.

	Feet.
Yellow clay	20
Yellow limestone	30
Brown soapstone	135
White limestone	100
Blue soapstone	30
White limestone	30
Blue soapstone	25
Shell rock	22
Brown sandstone (caving in)	27
White sand	28

Depth, 457 feet; cost, $457; 32 feet 4½-inch casing at bottom. Water comes within 50 feet of top. Will stand pumping 50 gallons per minute.—G. B. Morgan.

Tarrant County, Fort Worth.—Well belonging to R. H. King. Six-inch hole.

	Feet.
Clay and sand	31
Yellow limestone	2
Blue soapstone	45
White limestone	83
Blue soapstone	25
Shell rock	25
Brown sand	27
Good white sand	25

Depth of well, 263 feet. Cost, $263. Forty-five feet 4½-inch casing at bottom of well. Water very soft. Used by six families and irrigates a garden. Water within 30 feet of surface.—G. B. Morgan.

Erath County, Thurber.—Texas and Pacific Coal Company's artesian well.

	Feet.
Soapstone and shale	70
Coal (30 inches)	2½
Blue slate	187½
Blue slate and sand	220
Blue slate	26½

	Feet.
Sandstone	18
Blue slate	21
Shale and sand	87
Blue shales	38
Shale and sand	118
Blue shale	55
Sandstone	78
Slate and sand	37

At 480 feet one-quarter inch of coal. At 545 feet small strata of coal.

Haskell County, Haskell post office.—Common wells.

Black alluvial	2 to 4 feet.
Chalky clay and lime formation	6 inches to 6 feet.
Red clay	10 to 20 feet.
Fine sand and gravel	6 inches to 1 foot.
Blue limestone	6 inches to 2 feet.
Stratas of clay	3 feet to 10 feet.

Young County, Farmer post office (altitude, 2,250 feet).—Pettitt well; depth 132 feet.

Loam	6 feet.
Rock sand	13 feet.
Joint clay (clay marl)	25 feet.
Sandstone	6 feet.
Clay	10 feet.

Balance clay, slate, and sandstone. Water too salt; no flow. Another well, 240 feet, also salt water.

Chemical analyses of Texas wells.

McLennan County, Waco.—Bell waterworks, artesian wells.

	Grains per gallon.	Parts per 100,000.
Chloride of sodium	5.3418	9.16
Sulph. of soda	23.9103	41.00
Carb. of soda	25.2632	43.32
Carb. of calcium	1.4579	2.50
Alumina and iron	.1457	.25
Silica	.7464	1.28
Carbonic acid	....	21.03
Total United States gallons	56.8653	118.54
Total residue by evaporation	59.9216	102.75

Carbonic acid gas, 24.71 cubic inches.

McLennan County, Waco.—Artesian well water. In grains per United States gallons.

Silica	1.0356
Alumina	Trace.
Iron sesquioxide	.1493
Sodium chloride	6.0267
Sodium and potassium sulph	23.9483
Sod. carb. and bicarb	20.6587
Calcium sulph	
Calcium carbonate	1.1579
Magnes. carb	.8432
Total solids by calculation	53.8201

Surface well water:

Silica	.7790
Alumina	Trace.
Iron sesquioxide	Trace.
Sod. chlor	3.2016
Sod. and potass. sulphates	.4483
Sod. carb. and bicarb	
Calcium sulph	1.5444
Calcium carb	17.1072
Magnesium carb	.6710
Total solids by calculation	23.7518
Total solids by determination	24.0820

Bexar County, San Antonio.—General Russ' artesian well, 3 miles from town. Analysis by Professor Langenbeck, Cincinnati, Ohio:

	Grains.
Silica	1.34
Alumina and iron	1.14
Carb. of lime	12.64
Carb. of magnesia	5.35
Carb. of soda	1.56
Sulph. of soda	2.40
Nitrate of soda	1.41
Chloride of sodium	4.08
Free carbonic acid	16.08

West End. Town Company, two artesian wells. Depth, 260 feet; flow, 150 gallons per minute; wells cased 30 feet to rock.

Analysis prepared by Carl Langenbeck, Miami Medical College:

	Parts in 100,000 parts of water.
Silica	1.24
Alumina and iron	1.14
Carbonate of lime	12.64
Carbonate of magnesia	5.35
Carbonate of soda	1.56
Sulphate of soda	2.40
Chloride of sodium	4.08
Free carbonic acid	16.08

Chemical analyses of Texas wells—Continued.

La Salle County, Cotulla.—Depth of well, 1,008 feet; jets above ground 6 feet. An analysis made by Professor G. Bade, Milwaukee, Wis., is as follows:

	Grains.
Chloride of sodium	70.5217
Sulph. of potassa	24.8391
Sulphate of soda	55.4048
Bicarbonate of soda	52.6437
Bicarbonate of lime	5.7037
Bicarbonate of magnesia	3.4047
Bicarbonate of protoxide of iron	0.0072
Alumina	0.1053
Silica	0.9068
Grains to gallon	213.6000

El Paso County, city of El Paso.—Southern Pacific Railroad well (altitude, 3,717 feet).

	Grains.
Sod. chlor	27.01
Calcium sulph	12.23
Calcium carbonate	20.96
Magnes. carb	.79
Magnes. sulph	20.10
Silicates	2.95
Oxides and organic	.12
Total	84.06

Grains per gallon, 57.05.

El Paso County, city of El Paso.—Same well, but bottom water.

	Grains.
Sod. chlor	24.47
Sod. sulph	6.34
Calcium sulph	14.69
Magnes. carb	3.46
Magnes. chlor	9.16
Silicate	2.17
Total grains per gallon	60.28

El Paso County, city of El Paso.—Atchison, Topeka and Santa Fé Railway well.

	Grains.
Sod. chlor	18.00
Sod. chlor	8.12
Calcium sulph	1.55
Calcium carb	7.38
Magnes. carb	1.40
Magnes. sulph	2.22
Silicates	1.37
Total grains per gallon	32.04

El Paso County, Haskell.—Southern Pacific Railroad (altitude, 4,013 feet).

	Grains.
Carbonates of magnesia and soda	3.50
Salts of lime	10.15
Organic	1.70

El Paso County, Finley.—Southern Pacific Railroad (altitude, 3,945 feet).

	Grains.
Carb., chlor., sulhp. of mag. and soda	56.35
Carb. and sulph. of lime	5.63
Alumina, silicates, and organic	1.70
Total grains to gallon	63.15

Depth of 972 feet.

El Paso County, Fort Hancock.—Southern Pacific Railroad (altitude, 3,519 feet).

	Grains.
Carb., chlor., and sul. of mag. and soda	5.35
Carb. and sul. of lime	10.20
Alum, silica, and organic	1.20

Warner's well:

Carb., chlor., sul. of mag. and soda	2.30
Carb. and sulph. of lime	14.50
Alum, silicates, and organic	4.85

El Paso County, San Elizario.—Southern Pacific Railroad (altitude, 3,630 feet).

	Grains.
Chlorates and chlorides and sulphates of magnesia and sodium	55.75
Lime	62.35
Alum, silica, and organic	10.15

Dug well, 24 feet 6 inches; 6 feet 2 inches water; slightly turbid, foams, and is liable to incrustation.

El Paso County, El Paso City.—Round House well:

	Grains.
Carb., chlor., and sul. of mag. and soda	17.15
Salts of lime	26.30
Alum, silica, and organic	.70

Stout's brickyard:

Carb., chlor., and sulp. of soda and mag.	17.23
Salts of lime	15.60
Alum, silicates, and organic	.65

Another well:

Carb., chlor., and sul. of mag. and soda	11.50
Salts of lime	20.15

Forty feet deep; liable to incrustation.

El Paso County, El Paso City—Atchison, Topeka and Santa Fé Railway.

	Grains.
Carb., chlor., and sul. of mag. and soda	28.60
Salts of lime	41.55
Alum, silicates, and organic	1.05

Total, 71.20 grains to gallon.

Pecos County, Langtry Springs.—Southern Pacific Railroad well (altitude, 1,321 feet).

	Grains.
Lime, magnesia, soda	4.75
Lime	25.10
Silica and organic matter	1.85
Total grains per gallon	31.70

Pecos County, Dryden.—Southern Pacific Railroad well (altitude, 2,109 feet).

	Grains.
Carbonates, chlorides, and sulphates of magnesium and sodium	1.25
Carbonates and sulph. of lime	13.70
Alumina, silica, and organic	2.40
Total grains to gallon	17.35

Southern Pacific Railroad well, later test.

Carb., chlor., sulph. of mag., and soda	4.70
Carb. and sulph. of lime	21.10
Alumina, silicates, and organic	1.05
Total grains to gallon	26.85

Pecos County, Lozier (altitude, 1,535 feet).

Carb., chlor., sulphides of magnesia and sodium	2.75
Carb. and sulph. of lime	18.35
Alumnia, silicates, and organic	1.10
Total	22.20

Water clear and transparent. Bored well, 10 inches in diameter, 256 feet deep, 92 feet of water 900 gallons per hour. Pumps dry in three hours.

Pecos County, Sanderson.—Southern Pacific Railroad well (altitude, 2,780 feet).

	Grains.
Carbonates, chlorides, sulphates of magnesia and soda	9.15
Carbonates and sulph. of lime	5.10
Alumina, silica, and organic	4.35
Total grains	18.60

Chemical analyses of Texas wells—Continued.

Buchel County, Haymond.—Southern Pacific Railroad well (altitude, 3,883 feet.)

	Grains.
Carb,, chlor., sulph. of sod. and magnes	15.65
Carb. and sulph. of lime	26.10
Organic	1.40
Total grains to gallon	43.15

Old well incrustates boilers, on account of lime.

Southern Pacific Railroad (altitude, 3,883 feet). New well.

	Grains.
Carbonates, chlorides, sulph. of soda and magnesia	27.50
Carb. and sulph. of lime	12.15
Organic	1.85
Total grains per gallon	41.50

Slightly opalescent and will foam.

Another well:

	Grains.
Carb., chlor., and sulp. of sod. and mag	14.35
Carb. and sulph. of lime	36.20
Alumina, silica, and organic	13.60
Total grain	64.15

Slightly opalescent.

Buchel County, Marathon.—Southern Pacific Railroad (altitude, 4,043 feet).

	Grains.
Carb., chlor., sul. of mag. and sod	2.90
Carb. and sulph. of lime	21.15
Alumina, silica and organic	1.60
Total grains in gallon	25.65

Dug well 7 feet 2 inches by 7 feet 2 inches; 101 feet deep, 13 feet water, curbed 82 feet.

Jeff. Davis County, Valentine.—Southern Pacific Railroad (altitude, 4,424 feet).

	Grains.
Carb., chlo., sulph. of sod. and magnes	1.75
Carb. and sulph. of lime	4.50
Silica, alum, and animal matter	1.90

340 feet deep, 260 feet water.

Hot water:

Carb., chor., and sulph. of sod. and mag	3.50
Carb. and sulph. of lime	9.20
Alum, silicates, and animal matter	3.45

Turbid, foams on concentration.

Second well.

Carb., chor., sulph. of sod. and mag	1.85
Carb. and sulph. of lime	7.15
Alum, silica, and animal matter	1.35

Water opalescent, holding 10.35 grains in solution. Well 482 feet deep, 210 feet water, cased to bottom.

Presidio County, Marfa.—Southern Pacific Railroad (altitude, 4,692 feet).

	Grains.
Carb., chlor., and sulph. of sod. and mag	2.10
Carb. and sul. of lime	13.65
Alum, silica, and animal matter	1.60

Twelve hundred feet deep, 8 inches diam., 1,000 feet of water.

Lampasas County, Lampasas.—Hancock Sulphur Springs. Analysis by E. Waller, Ph. D., of New York. (Per United States gallon, 231 cubic inches.)

	Grains.
Chloride of sodium	49.836
Bromide of sodium	Trace.
Bicarbonate of lithia	0.186
Bicarbonate of lime	24.282
Bicarbonate of iron	0.052
Chloride of magnesium	18.265
Chloride of calcium	9.040
Sulphate of potassa	2.024
Sulphate of lime	2.462
Alumina	0.059
Silica	0.496
Organic matter	Trace.
Total	106.701

Robertson County, Wootan wells.—A famous health resort. Analysis (United States gallon) by Prof. C. F. Chandler, New York.

Well No. 1:

	Grains.
Chlorine in chlorides	23.341
Magnesia	13.110
Lime	25.211
Protoxide of iron	1.917
Sesquioxide of iron	0.989
Sesquioxide of alumina	1.220
Oxide of manganese	0.542
Sul. acid in sulphates	59.671
Silicia	3.282
Organic and volatile	9.623

Well No. 2.—Analysis by Dr. W. M. Mew, chemist U. S. Navy Department, Washington:

	Grains.
Chlorine in chlorides	33.132
Magnesia	11.376
Lime	25.892
Iron as sesquioxide	11.080
Alumina as sesquioxide	1.565
Oxide of manganese	0.436
Sul acid in sulphates	67.227
Soda	14.579
Silica	2.823

Well No. 3.—Analysis by Prof. C. F. Chandler, New York:

	Grains.
Chlorine in chlorides	35.457
Magnesia	17.495
Lime	27.100
Oxide of iron, alumina and manganese	15.052
Sul. acid in sulphates	79.254
Organic and volatile matter	12.247

Well No. 4.—Analysis by Prof. W. M. Mew, chemist, U. S. Navy Department, Washington:

	Grains.
Chlorine in chlorides	36.357
Magnesia	22.750
Lime	28.108
Iron as sesquioxide	13.063
Alumina as sesquioxide	13.456
Oxide of manganese	0.571
Sul. acid in sulphates	86.408
Soda	18.100
Silica	4.083

Webb County, Laredo—Flowing well 75 feet deep, analysis by George Kolteyer. One gallon filtered water contains 103 grains of solid mineral salts, but entirely free from organic matter. The mineral salts consist of soda, potash, and sulphuric acid, of which there is a large percentage of sulphate of soda and a small quantity of potash.

Bexar County, San Antonio.—G. A. Kampmann's artesian flowing well. Analysis by James Kennedy, Ph. G.

	Grains.
Sodium chloride	26.528
Magnesium sulphate	25.344
Sodium sulphate	8.410
Calcium bicarbonate	4.845
Magnesium bicarbonate	Traces.
Sodium thiosulphate	2.205
Sodium biborate	Traces.
Lithium chloride	Traces.
Potassium chloride	0.165
Earthy phosphates	Traces.
Ferrous sulphate	Traces.
Silica	2.640
Alumina	0.510
Ammonium nitrate	Traces.
Total	70.647
	Cu. in.
Sulphuretted hydrogen	3.66

Railroad water supply.

[West of the ninety-seventh meridian in Texas.]

GALVESTON, HARRISBURGH, AND SAN ANTONIO RAILROAD COMPANY.

Location.	Altitude.	Remarks.
	Feet.	
El Paso, El Paso County	3,713	Two circular wells, each 20 feet in diameter and each 28 feet deep, curbed with 3-inch cypress plank; water stands in wells at same level as water in Rio Grande, and any amount of pumping fails to lower it; a surface pump; capacity, 7,500 gallons per hour.
Fabens, El Paso County.....	3,614	Same as at El Paso in every particular, except that wells are 32 feet deep.
Fort Hancock, El Paso County.	3,519	The same as at El Paso, except that wells are 42 feet deep.
Finlay, El Paso County......	3,945	1,080 feet deep; diameter 8 inches at mouth and at bottom; very bad water at 396 feet; abandoned.
Sierra Blanca, El Paso County.	4,512	943 feet deep; 5⅝ inches diameter at mouth and bottom; unlimited supply of poor water; deep well, walking-beam pump; capacity, 1,800 gallons per hour.
Torbert, El Paso County	4,343	1,100 feet deep; diameter at mouth 8 inches, at bottom 5⅝ inches; small stream of fair water at 696 feet from top; well abandoned.
Haskell, El Paso County	4,013	2,029 feet deep; diameter at mouth 12 inches, at bottom 7⅝ inches; use air-compressor pump of 1,500 gallons per hour capacity, which exhausts the well in three hours.
Valentine, Jeff Davis County.	4,424	1,245 feet deep; diameter at mouth 5⅝ inches, at bottom 3 inches; unlimited supply of excellent water; deep well, walking-beam pump; capacity, 1,200 gallons per hour.
Marfa, Presidio County......	4,692	197 feet deep; dug 10 by 10 feet square; unlimited supply of fair water; double-acting surface pump; capacity, 5,000 gallons per hour.
Alpine, Brewster County ...	4,485	Supply comes from springs; water fair; 6 hours pumping, with 6,000 gallons per hour; pump exhausts the springs.
Marathon, Buchel County ...	4,093	102 feet deep; dug well 10 by 10 feet square; unlimited supply of good water; single-acting deep well pump; capacity, 3,000 gallons per hour.
Haymond, Buchel County...	3,883	15 feet deep; dug well 10 feet in diameter; unlimited supply of very poor water; abandoned.
Taber, Buchel County.......	....	46 feet deep; dug 16 feet square; unlimited supply of good water; surface pump, 6,000 gallons per hour capacity.
Maxon Springs, Buchel County.	3,538	1,004 feet deep; diameter at mouth 9½ inches, at bottom 4½ inches; furnished all the water necessary; well now abandoned on account of better water and easier to get at Taber.
Longfellow, Pecos County...	3,274	683 feet deep; diameter at mouth and bottom 8 inches; unlimited supply of fair water; air-compresser pump; capacity, 1,250 gallons per hour.
Sanderson, Pecos County....	2,780	987 feet deep; diameter at mouth and bottom 7⅝ inches; air-compresser pump; capacity, 1,700 gallons per hour; large supply of good water.
Dryden, Pecos County.......	2,109	1,797 feet deep; diameter at mouth 7⅝ inches, at bottom 4 inches; unlimited supply of good water; air-compressor pump; capacity, 1,000 gallons per hour.
Lozier, Pecos County........	1,535	770 feet deep; diameter at mouth and bottom 7⅝ inches; limited supply of good water; air-compresser pump; capacity, 1,000 gallons per hour, which exhausts well in two hours; it then takes two hours to fill up.
Cline, Kinney County	1,007	40 feet deep, 12 by 12 feet square; unlimited supply of good water.

Railroad water supply—Continued.

TEXAS PACIFIC RAILWAY WELLS.

Fort Worth, Tarrant County	629	Two artesian pumping wells and storage reservoir; daily capacity, 100,000 gallons.
Aledo, Parker County	870	Dug well; 40,000 gallons daily.
Weatherford, Parker County	870	Dug well; 18,000 gallons daily.
Rock Creek, Parker County	....	Well; supply limited.
Strawn, Palo Pinto County	900	Dug well; 50,000 gallons daily.
Cohrey Fork, Callahan County	1,524	Well; 6,500 gallons daily.
Delmar, Callahan County	1,600	Artificial pond.
Van Horn, El Paso County	4,610	Four bored wells, 600 feet; unlimited supply.
Baird, Callahan County	1,524	Artificial pond.
Clyde, Callahan County	2,025	Two dug wells; 10,000 gallons per diem.
Merkel, Taylor County	1,875	Well, dug and bored; 40,000 gallons per diem.
Loraine, Mitchell County	2,297	Well and pond; 60,000 gallons per diem.
Colorado, Mitchell County	2,075	Deep well; 24,000 gallons per diem.
West Brook, Mitchell County	2,100	Artificial pond.
Iatan, Mitchell County	2,200	Do.
Big Spring, Howard County	2,400	The Big Spring; 100,000 gallons per diem.
Marienfeld, Martin County	2,700	Dug well; 24,000 gallons per diem.
Midland, Midland County	2,780	Dug well; 60,000 gallons per diem.
Odessa, Ector County	2,900	Dug well; 50,000 gallons per diem.
Monahans, Winkler County	2,620	Three dug wells; 200,000 gallons per diem.
Pecos City, Reeves County	2,590	Artesian well; 60,000 gallons per diem.
Toyah, Reeves County	2,975	Artesian well; not used.
Saw Martine Spring, Jeff Davis County.		8,000 gallons per diem.

GULF COLORADO AND SANTA FÉ RAILWAY.

Weatherford, Parker County	....	Dug well, 25 feet diameter, 68 feet deep; carries 30 feet of water. Daily capacity, 50,000 gallons. Strata red loam 14 feet, 24 feet limestone, leaky; below this layers of blue clay, sand and water in gravel. At water line, traces of iron.

FORT WORTH AND DENVER RAILWAY.

Newlin Station, Hall County	....	6-inch bore, 550 feet deep; four different layers of salt water; well abandoned.
Armstrong, Armstrong County.	....	5⅝-inch bore, 292 feet deep; good water in sand and gravel; yields 30 gallons per minute.
Hartley Station, Hartley County,	....	5⅝-inch bore, 375 feet deet; good water and abundant.
Texline, Dallam County	....	270 feet deep; good water that rises to within 25 feet of the surface; pumps 70,000 gallons per diem, and supplies division round house.

WATER SUPPLY OF TEXAS CITIES AND TOWNS.

San Angelo, Tom Green County.—Supply from North Concho River, 500,000 gallons daily. Cost of plant, $29,000. Can deliver water at 35 cents per 1,000 gallons. Use compound duplex steam pumps.

Denison, Grayson County.—Supply obtained from springs and tunnels. One tunnel is about 3,000 feet long with twelve wells on its line. Tunnels and four small creeks afford a fair supply. Storage reservoir costing $8,000, holds 80,000,000 gallons. It costs 9 cents per 1,000 gallons to furnish water. Pressure at pumps 120 pounds; in the city 75 pounds. Cost of the works $200,000.

Gonzales, Gonzales County.—Supply from Guadalupe River. Cost $18,000. Capacity 300,000, gallons in 24 hours. Forty horse power Worthington steam pump. Use stand-pipe; 60,000 gallons capacity.

Seguin, Guadalupe County.—Supply from Guadalupe River. Cost of plant $27,000. Daily capacity 500,000 gallons. Price per 1,000 gallons 25 to 50 cents, according to quantity used. Gordon & Maxwell duplex power pump and Gordon & Maxwell duplex steam pump. The power for pumping is obtained from a natural dam in Guadalupe River, steam only used during high water.

Paris, Lamar County.—Supply obtained from dug wells tunneled. Cost, $100,000. Use two Worthington pumps, each 1,000,000 gallons capacity in twenty-four hours. Ten miles distributing mains and eighty-six fire dydrants.

Palestine, Anderson County.—Supply from two artificial lakes supplied by springs. Cost of plant $150,000. Daily capacity 500,000 gallons. Price of water 25 cents per 1,000 gallons with discount to large consumers. Use Worthington pumps, two of them. Lake dam built of pipe clay sunk in sand 30 feet, about 500 feet long, and 20 feet above the surface. Cost $20,000. The other dam is a fill about 400 feet long and 25 feet high, and cost $7,000. They retain about 20 acres of water 6 to 25 feet deep. About 300 springs feed these lakes. Standpipe 150 feet high, 100 feet above the pumps, and 50 feet above the city.

Brownwood, Brown County.—Water supply from Pecan Bayon. Cost of plant, $46,000. Capacity, 24 hours pumping, 2,400,000 gallons. Standpipe, 20 by 100 feet, 5 miles mains, and thirty-seven double hydrants.

Brenham Washington County.—Supply from surface wells 25 feet deep. Capacity, 300,000 gallons daily. Can furnish water at 10 to 15 cents per 1,000 gallons. Use Deane compound duplex pumps. Two wells 25 feet diameter, 25 feet deep. Depth of water 12 feet. One well 40 by 60 feet, 25 feet deep, water 12 to 14 feet. Wells replenish rapidly. Cost of plant, $70,000.

Temple, Tex.—Supply from surface wells and Leon River. Use two Worthington pumps, each 750,000 gallons capacity per diem, and one Dean high-pressure pump of same capacity. Cost of water delivered about 3 cents per 1,000 gallons. Cost of plant, $95,000.

Abilene, Taylor County.—Supply from Lytle Creek, east of town. Capacity about 250,000 gallons daily. One hundred foot standpipe and fire hydrants.

Morgan, Bosque County,—One artesian well, flowing 20 gallons per minute, into a wooden tank 50 feet above ground and above town. Pipes on the principal streets for use in case of fire.

Navasota, Grimes County.—Artesian pumping wells, 250 feet and 830 feet deep. Afford 100,000 gallons daily.

Weatherford, Parker County.—Supply from one dug well 47 feet deep, 12 feet diameter, with three tunnels each 100 feet long. One bored well 402 feet deep. Use two compound duplex Dean pumps for dug well, and walking beam deep well pump for bored well. Daily capacity about 100,000 gallons. Price of water 50 cents per 1,000 gallons for small consumers, and 10 cents for parties using as much as 40,000 gallons. Have a distributing reservoir holding 1,100,000 gallons 80 feet square.

Laredo, Webb County.—Supply from driven wells on an island of sand and gravel in the Rio Grande. Six dug wells in gravel bed 18 by 16 feet from 7 to 9 feet deep to bed rock; one receiving well 16 feet diameter, 35 feet deep, excavated in rock fed by two 12-inch pipes from driven wells on island, fifty-five 2-inch driven wells connected by 6-inch pipes to the dug wells and worked by syphon. Cost to date $130,000. Capacity of pumping engines 4,000,000 gallons. Cost of pumping 5 cents per 1,000 gallons. Use two Blake Duplex and one Worthington compound condensing pumping engine.

Waco, McLennan County.—Two water works companies, both using artesian wells, varying in depth from 1,820 to 1,852 feet. The daily output of the Bell water works from four artesian wells is 3,800,000 gallons, the Waco Water and Power Company furnishing 1,200,000 gallons additionally. The wells are situated 85 feet above the city, and the pressure of the wells is sufficient to overflow the 80-foot standpipes, placed above the mouth of the wells. The pressure of water at mouth of the wells is 59¾ pounds. Temperature 102 degrees.

Colorado City, Mitchell County.—Water supply obtained from two bored wells, respectively 150 and 180 feet deep, 8-inch bore. A steam pump is used in one well and a 30-foot United States windmill in the other. The windmill generally supplies all the water required by the population, about 2,500. A standpipe 22 by 100 feet is used.

SEMIARID REGION, DISTRICT NO. 2.

This district comprises all that portion of Texas lying between the one hundredth and one hundred and third meridians, and north of Pecos River, south of a point where the one hundred and third meridian crosses said river and extending from the Public Land Strip south to

the Rio Grande. The area is about 83,725 square miles. The altitudes of various points in the district are given as follows:

	Feet.
Southern Pacific Railway stations:	
Langtry	1,321
Shumla	1,418
Painted Cave	1,006
Comstock	1,556
Devil's River	972
Del Rio	955
Johnstone	1,082
Spofford Junction	1,015
Nueces	942
Texas and Pacific stations:	
Trent	1,920
Sweetwater	2,175
Loraine	2,297
Colorado	2,075
Westbrook	2,100
Iatan	2,200
Signal Mountain	2,430
Big Spring	2,400
Texas and Pacific stations—Cont'd.	
Morita	2,475
Marienfeld	2,700
Germania	2,775
Midland	2,780
Odessa	2,900
Douro	3,100
Monahan's	2,620
Pecos River	2,590
Fort Worth and Denver Railway at one hundred and third meridian	4,700
Government observations at—	
Camp Lancaster	2,350
Howard's Well, Crockett County	2,054
Fort Concho, Tom Green County	1,888
Goodnight, Armstrong County	3,100

The rainfall varies from 15 inches on the line of New Mexico and the Pecos River, to 30 inches along the one hundredth meridian.

Flowing artesian wells.

County and post-office.	Owner or informant.	Depth.	Cost.	Remarks.
Dallam County:				
Tascosa	Lee Scott Cattle Company.	230	$450	15 gallons per minute.
Hockley County	Syndicate Ranch	75		Water just comes to surface; flows 3-inch stream with force.
Lubbock County:				
Yellow House Pasture.	McCluskey	64		Flowing.
Singer's Store	Dave Taylor	Not deep.		Constant 2-inch stream, rising 4 feet above surface.
Midland County:				
Midland	G. G. Gray	15	25	500 gallons per minute.
Tom Green County:				
San Angelo post-office.	Titus Machine Company, 50 miles from San Angelo.	960		1 inch stream.

Hockley County. W. S. Marshall, Fort Worth, well-driller. There are three artesian wells in Hockley County. First well had a weak flow. When second well was bored 100 feet distant, the supply diminished to one-half in the first well. The two wells furnish 5 gallons per minute, originally furnished by the first; depth, 120 feet. One well $1\frac{1}{2}$ miles distant yields 4 gallons per minute, on same level as the others; depth, 120 feet. In draw of Yellow House Cañon.

Several flowing wells said to have been bored in this county. No accurate information obtainable at this time.

I. H. Peters, of Fort Worth, says he "has bored wells in Texas for eighteen years. Tom Green County and country west to Pecos River underlaid with pack sand with plenty of water at 100 feet to 500 feet. Have also found second, third, and fourth stratas of sand, at about 100 feet apart, always finding stronger streams the deeper the bore."

NEGATIVE ARTESIAN WELLS.

There are several thousand of these in this district. The water rises in a majority of wells, showing thereby that the water is under considerable pressure and often comes from a great distance. The distances between places are so great in this region that accurate locations can not be given.

Andrews County, Chicago Ranch.—W. T. Stewart, formerly well-driller, bored twenty-one wells in Andrews County, the deepest 90 feet and the shallowest 47 feet. In all the wells the water rises, and in quite a number the water is within 1 to 20 feet of the top of the well. Work was generally discontinued in order to avoid a flow, the owners of the ranch being desirous to avoid the congregation of cattle in one place. At 200 feet a flow may be confidently expected.

On Montgomery survey, about 6 miles north of block 41, township 1 south, is a drilled well 72 feet deep, in which the water rises to within 12 feet of the top. A Rider hot-air pump, with 6-inch cylinder, does not lower the water line.—M. B. Cranson, Midland.

Andrews County.—Informant, M. B. Cranson, well-driller, Midland. Five miles north of last-mentioned well is a ravine in which water in abundance can be found at the depth of a spade, and then be run into ditches.

On the Montgomery survey there are forty wells, varying in depth from 40 to 100 feet. The water rises in every one of them, and in many almost to the surface of the ground.

Altitude of Chicago Ranch about 2,875 feet.

Armstrong County.—Altitude at Goodnight about 3,100 feet.

Bailey County.—Information from W. S. Marshall, Fort Worth, Tex. In twelve wells, bored about 200 feet, the water rises almost to the surface.

Carson County.—Mark Huselby, Mobeetie, Wheeler County, reports: "There has been a well bored in Carson County to depth of 320 feet, in which the water rises about 80 feet."

Crosby County, Mount Blanco.—(Altitude of wells, 2,605 feet. John F. Niley, of the Kentucky Cattle Raising Company, reports, "Our windmill wells on the plains are about 300 feet deep. Water rises in some of these 50 to 60 feet."

H. C. Smith, Mount Blanco, reports that several of this company's wells "would come to the surface, and flow a good stream of water if properly cased off."

Dallam County, Tascosa.—(Altitude 3,600 feet). J. C. Hatchell, Amarilla, Potter County, Tex.:

"The deepest well in this vicinity is about 240 feet, but there are many that are not 200 feet. The water is soft, and inexhaustible. Windmills are used for power; 6-inch casing is generally used. The water rises from 30 to 80 feet in the wells.

Donley County.—James H. Parks, Clarendon, Tex.:

"We have numerous bored wells in this and adjoining counties that find water at from 50 to 250 feet. In some of these the water has risen from 40 to 80 feet. The deeper the well the higher the water usually rises."

Ector County.—W. T. Stewart, formerly well-driller at Midland: "On Creighton's Ranch, 6 miles north of Warfield are three wells each 160 feet deep. The water is excellent, rising 30 feet in each well. Bored one hundred and sixty-four wells on the Staked Plains, and got water in each and every well."

Armstrong, Donley, Crosby, Swisher, and Oldham.—Information from J. E. Brownsfield, Colorado, Tex.:

"The Goodnight cattle ranches are located in these counties, and the owner of the ranches has bored therein sixty-nine wells, ranging in depth from 40 to 300 feet. Most of them are about 110 feet deep. The average cost is about 60 cents per foot, and a 3-inch cylinder and 1½-inch exhaust pipe are generally used. All of the wells are 8-inch bore, and the usual yield of each is 150 gallons in five hours' pumping. Twenty-four of these wells are situated in the Palo Duro Valley, the remainder on the upland plains. In Swisher County, away from the Palo Duro Cañon, the wells are from 18 to 20 feet deep. In most of the wells above mentioned the water rises, and in some as much as 150 feet. In the adjoining counties water is readily obtained by digging for it. As a rule the water obtained is of excellent quality, but in a limited number the water is salty."

Floyd County.—Information from C. H. Earnest, Colorado City, Tex.:

"About one hundred and twenty-five wells in the county, the average depth of which is from 20 to 30 feet, the deepest well being about 50 feet. The water rises from 10 to 25 feet above the point where found in every well. Ten-foot or 12-foot windmills are extensively used for raising water."

Glasscock County.—D. N. Morrison, Garden City, well-driller:

"South of this point the wells are from 100 to 250 feet deep, and the rock is solid, excepting from 4 to 10 feet of soil and clay. The water is plentiful and of fine quality and rises from 4 to 20 feet in each well."

W. P. Stewart, formerly well-driller:

"Bored nine wells on McIntyre & Barnett ranch and ten others in Glasscock County. The deepest 90 feet and the shallowest 60 feet. The water rose in all the wells."

Ector County.—J. W. Otterman, Odessa, Tex.:

"There are 45 wells in the county. About one-fourth of them are bored. Average depth, 100 feet; cost, $1.25 to $1.50 per foot, 6-inch bores. Supply can not be exhausted by 12-foot windmill and pump to correspond. There are five veins of water, the lower ones being softer than the first. The water in many bored wells rises higher than the point where struck, in one case 17 feet above the place where water was reached."

Hartley County.—C. F. Conklin, Hartley, Tex.:

"It is demonstrated that by boring wells an inexhaustible supply of water can be obtained. In this immediate section 4-inch wells have been sunk and water struck at 420 feet. It rises some 30 to 40 feet at being tapped. Up the Fort Worth and Denver road other wells were struck, that sent water to within 30 feet of the surface."

Hansford County.—Ralph Bigger, Hansford, Tex.:

"On section 136 an attempt was made to reach artesian water, but the machine failing to work satisfactorily, the well was abandoned at 130 feet, with about 70 feet of water."

Hale County.—I. F. Graham, Plainview:

"I am satisfied there can be flowing water had here, as all along the foot of the Plains (Staked) large springs break out. All the wells drilled here rise more or less from 5 to 60 feet."

Hale County.—Information from C. H. Earnest, Colorado City, Tex.:

"There are about one hundred and twenty-five wells in the county, most of them bored. The shallowest is 6 feet deep and the deepest 50 feet. Nearly all wells are pumped by 10 and 12 foot windmills of various makes. The average cost of well windmill and pump in Hale County is from $110 to $150, and this includes boring and casing. It is the impression that artesian water could be obtained in this county, for the reason that every well bored has had the water rise from 10 to 25 feet."

Howard County.- County artesian well. Depth 600 feet. The water is salty, but stands about 4 feet from the surface.

Lipscomb County.—John Wanger, Timms City, Tex. Altitude 2,600. "G. R. Timms well section 1036; block 43. Well drilled 227 feet deep and has 127 feet of water, the same being struck at 150 feet."

"E. C. Gray, Higgins, Tex. A well was bored at Timms City to a depth of about 320 feet, and only partly curbed. At 200 feet they struck water of artesian strata which rose in the well about 170 feet. The parties boring the well had to abandon the project on account of poor machinery and being unable to procure better."

Howard County.—W. T. Stewart, formerly well-driller.

"Bored a well 16 feet deep, 2½ miles north of Morita Station and secured an immense supply. The water is good and comes within 3 feet of the top of well.

"Bored a well on Denmark ranch, 6 miles north of Texas & Pacific Railway on west line of Howard County, 16 feet deep, 6-inch bore. The water is 2½ to 3 feet from surface, and can be syphoned to lower, lying land. Mr. Denmark irrigates 7 acres with it, using a windmill."

Lynn County.—J. D. Birdwell, Big Springs, Tex.

"In a well 6 miles north of south line of county, 282 feet deep, a small stream of water that rises within 70 feet of the surface. Only one vein of water found in well."

Martin County.—Wells in the east half of the county from 40 to 140 feet deep; in the west half from 20 to 50 feet; in the draws or old river channels from 3 to 20 feet. Water rises in all the wells.

Midland County.—Information from M. B. Cranson, well-driller, Midland, Tex.

"In the county of Midland there are over 400 wells, of which 100 are in the town of Midland. The wells in town vary from 30 to 65 feet in depth; 48 of them are pumped by windmills. In the county the wells vary from 2 feet to 200 in depth. The shallowest wells, 2 to 20 feet, are on the uplands in southern half of county; the deepest along the south line of the county. As a rule the water rises, and in most cases, from 40 to 60 feet. None of this water is dependent on local rains. It lies in sheets and is under pressure; the greater the depth of the well the greater the rise. This feature is regarded as indicating the presence of artesian water at a greater depth. J. W. Millican's well is bored 65 feet and carries 28 feet of water. It fills a tank holding 1,800 gallons every three hours. Cost of well $90 and of windmill and tank $50.

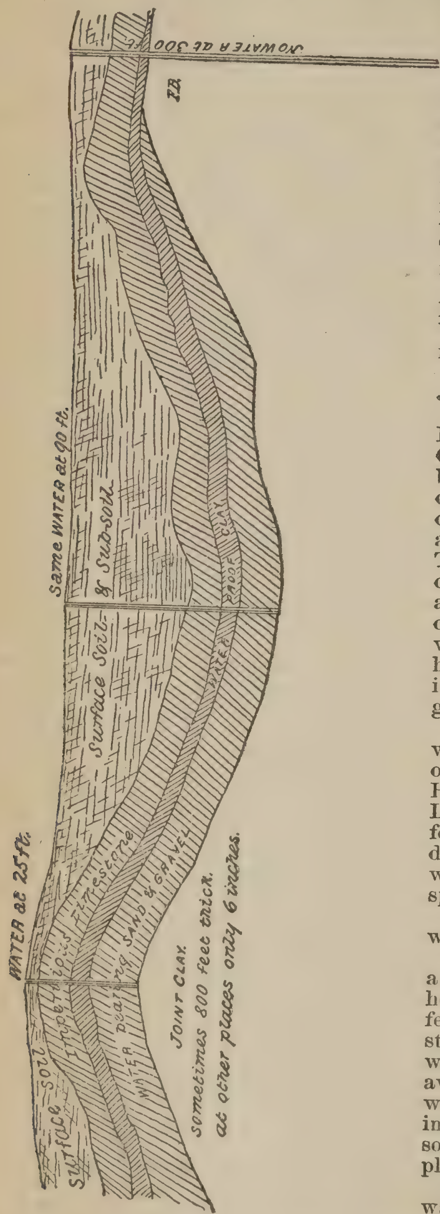
"Ward's well, 70 miles northwest from Midland, is simply plowed out, and the water supply is inexhaustible for ordinary uses.

Water in many places on the staked plains is found at the shallowest depth on the highest ridges, and often the valley water is the deepest. It appears that the stratification, though undulating, is continuous and unbroken, and that the water, being under pressure follows the contour of the country.

"In a few places this joint clay appears almost at the surface but generally there are from 5 to 7 sheets of water under pressure between it and the surface."

Mitchell County.—Lone Star Salt Company. Bored one well 8 inches diameter for 500 feet and 5 inches diameter for 620 feet. Depth of well 1,120 feet. Struck good water at 80 feet and again at 325 feet. Between 100 feet and 300 feet water was charged with iron, sulphur, and other ingredients. It was unfit for use of any kind, forming an evil-smelling scum that precipitates and, on drying, becomes scaly. At 500 feet more water, supposed to be good. At 820 feet struck salt, passing through

one layer of rock salt 30 feet thick, then 20 feet of rock, then 40 feet of salt, below the salt 200 feet of rock and water again at 1,120 feet, with sufficient pressure to raise the drill, weighing 4,500 pounds, high enough to kink the rope. The upper waters being cased off, the water level is now 300 feet from the top. The pump capacity used on the well is 30,000 gallons per diem, though the supply is considered unlimited. If the salt were cased off it is thought the bottom water would be good for general use. Temperature of water 71°. The well is used for manufacturing salt.



Texas Salt Company's wells at Colorado City. Four bored wells 5⅝ inches diameter, each well 1,000 feet deep. At 936 feet a body of water supposed to be pure (if the salt were cased off) that rises within 140 feet of the surface. The parties boring these wells feel satisfied that by boring 500 feet more they can bring fresh water to the surface. The four wells are pumped by 30-foot windmills.

The average depth of fresh-water wells in Mitchell County is from 100 to 200 feet. Water is often found at a lesser depth, but is generally unfit for use.

Lynn County (along north line).—W. V. Johnson, Colorado City:

"On the Llano, on the northern line of Lynn County, and lapping into Lubbock County, I have a cattle ranch supplied only by drilled wells. I have 70,000 acres inclosed and can provide comfortably for 8,000 cattle with my nine wells. Their depth is about 85 to 95 feet; altitude, 3,100 feet. They are drilled 7 inches in diameter and cased with 6-inch casing. The water is abundant, medium soft, clear, pure, and excellent. It rises some 40 to 50 feet in the wells and there stands apparently in inexhaustible supply. I lift it with windmills into large earthen tanks of 200,000 to 300,000 gallons' capacity.

"My observation extends to hundreds of wel s on the Llano Estacado, in the counties of Lynn, Lubbock, Garza, Crosby, Floyd, Hale, Hockley, Martin, Gaines, Terry, and Lamb. The depth varies from 30 feet to 150 feet, occasionally somewhat deeper. The deep wells are usually near the cañons, and where, I suppose, the water leaks out at the springs near the bottom."

Nolan County.—Ragland & Beall, Sweetwater, Tex.:

"We have no artesian wells in the county; a great many common-bored stock wells, however. These wells are from 125 to 250 feet deep. The water in some for most part stands within 70 to 80 feet of the top of the wells. They are 6-inch bore and cost, on an average, from $1 to $1.10 per foot. The water in the northern part of the county is impregnated, more or less, with gypsum. In southern portion it is free from any unpleasant mineral."

Nolan County.—Cowan & Fisher, Sweetwater, Tex.:

"Bored wells on the divide (between the waters of the Brazos and the Colorado Rivers) are from 150 to 300 feet deep, generally having a very limited supply until the depth of 300 feet is reached. The water then rises to within 16 feet of the surface."

Ochiltree County (altitude 2,500).—E. P. Kapp, Cresswell, Tex.: "The water does not rise any either in the dug or bored wells."

Ochiltree County (altitude 3,000).—Isaac A. Curry, Gilaloo, Tex.:

"There are wells on our plains ranging in depth from 190 to 220 feet. After securing water it rises in the well 15 to 20 feet."

Potter County.—J. C. Hatchell, Amarilla, Tex.:

"Water is obtained in this vicinity at an average depth of 200 feet. It rises from 20 to 80 feet, and is brought to the surface by windmills. It is clear and soft and is used for watering stock and farm purposes. The supply is inexhaustible."

Scurry County.—A. C. Wilmeth, Snyder, Tex.:

"We have no artesian wells in this vicinity, though we thoroughly believe we can secure one by boring 300 feet or more. Our locality is furnished water from wells about 40 feet deep on an average. We secure it in sandstone. I have one bored well, struck a light stream at 30 feet and at 50 feet struck a bold stream which rose to the first stream."

Tom Green County.—Titus Machine and Tool Manufacturing Company, San Angelo: About 30 miles southeast of here I drilled a hole 300 feet, and the water rose within 8 feet of the top. I am now drilling on a well. When I got 300 feet I struck salt water, oil, and gas. I cased it off, but a small quantity flows all the time outside of the casing. I went down 800 feet without striking any more. At this depth struck water and it rose 500 feet in the well. I am sure that we will get artesian water if we go deep enough.

Val Verde County.—M. H. Warren, Del Rio: B. L. Croucher's well, 30 miles north of Del Rio and 10 miles from Devil's River. Altitude 600 feet above Del Rio; depth 475 feet; cost, complete, $1,568.50. Six-inch bore. No flow, but an unlimited supply 300 feet from surface. Eighteen-foot windmill and 2½-inch pump.

Val Verde County.—M. H. Warren, Del Rio. B. N. White's well, 20 miles north from Del Rio and 12 miles from Devil's River, 475 feet above Del Rio. Depth of well, 300 feet; cost, $600. Water 250 feet from surface.

Hockley County.—W. S. Marshall, Fort Worth, Tex.:

"All wells bored in Hockley County show an inclination to rise 50 to 100 feet above the point where water is struck. I regard it as an indication of artesian territory. There are about 150 bored wells in the county.

"All of the central plains west of Blanco Cañon show indications of artesian water, because the water in all wells rises there."

Lubbock County.—There are about 50 wells, from 100 to 150 feet deep.

Lynn County.—Twenty or more wells, from 100 to 250 feet deep, are reported.

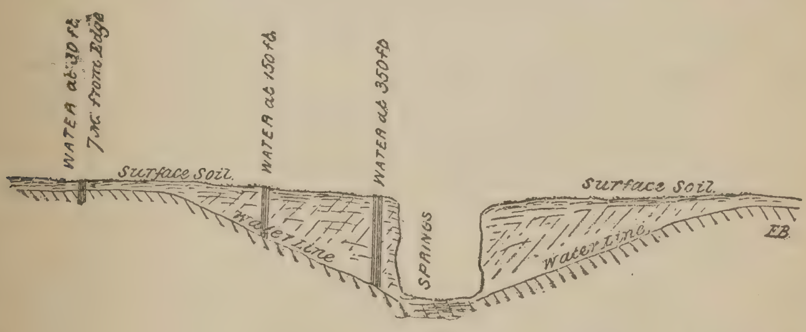
Terry County.—There are reported 20 or more wells, from 100 to 150 feet.

Lamb County.—About 20 wells are named.

Cockran County.—There are 8 reported.

Dawson County.—About 20 wells reported, from 175 to 250 feet deep; some less. Not much rise in these wells and more or less salt.

Hale County.—Water is generally found at 30 to 100 feet, and in Deaf Smith County at about 30 feet. Depth and pressure are dependent to a large extent upon continuity of surface. The water is always shallow and under pressure when distant from "breaks" or deep cañons, but lies deep and without pressure on the edges, thus:



The flow in the strata in the main comes from the northwest, and as the cañons trend southeast the springs are nearly always found on the north or northwest side of the cañon.

San Saba County.—J. H. Martin, San Saba.

"The average depth of wells in our county is from 20 to 30 feet. Many dried up in 1886 and then they were bored 100 feet deeper. The water in a great many of them then rose to the surface."

Midland County.—On Dunn and Steven Ranch, 12 miles south of Midland, are five wells from 60 to 90 feet deep. The water in all of these rises from 10 to 30 feet.

Stratification of wells, district No. 2.

Borden County.—Anthony Blum, Durham, Tex., on Sec. 230, Bl. 97, H. & T. C. surveys:

	Feet.
Surface soil	2
Red clay	4
Red clay mixed with decomposed limestone, gravel, and quartz pebbles	10

Coarse gravel, fine quicksand, and water (6 inches).

Sandstone soft on top, very hard on bottom	2

Joint or block clay, hard in layers and dark red. Sometimes 350 feet thick. Wells generally abandoned because no water is found in them. We can get no water except from the gravel and quicksand, which supplies the water to the several springs. No one has ever gone through the joint clay in this county.

Dallam County, Tascosa (altitude 3,000 feet).—Lee Scott Cattle Company:
Soil, clay, coarse sand, gravel, honeycomb rock.
No soapstone or slate in this part of the country.

Glasscock County.—J. I. McDowell's well:

	Feet.
Black sandy soil	5
Clay	20
Sand and water	5

Hockley County.—I. F. Graham, Plainview, Tex.:

	Feet.
Black alluvial soil	3
Impervious yellow clay	10
Boulders and gravel	17
Decomposed lime rock	10

This generally brings us to the water in this country. In some few places, we strike from 6 to 10 feet of sand.

Martin County.—

	Feet.
Soil	5 to 10
Decomposed lime rock	10 to 20
Hard flinty limestone	1 to 2

Hard conglomerate gravel 6 inches. Sometimes 6 inches red sandstone.

Yellow clay	1 to 3
Sand-gray shale and water	8 to 10
Clay	8 to 10
Sand, gravel, and water	8 to 10

Sometimes plenty of good water in the decomposed lime rock.

Lynn County (altitude 3,100 feet).—W. V. Johnson, Colorado, Tex.:

	Feet.
Surface, loam, gradually merging into clay	20
Limestone	15 to 25

Sandstone resting on a thin stratum of conglomerate; below this excellent water.

Gray County (altitude 3,700 feet):

	Feet.
Black alluvial soil	4
Clay	6
Rotten limestone and clay	10
White magnesia	10
Sandy clay	12
Red clay	15
Magnesia and gravel	11
Limestone	4
Sand	10
Lime rock	5
Red clay	10
Lime rock	4
Sandy clay	12
Lime rock	3
Sandstone in 4-inch layers	4
	120

This material is in F. W. Johns's well, 10 miles west of Mobeetie, in Gray County. There is no water at the depth I went worth anything, the supply being inadequate for family use. Close by I got plenty of water at 130 feet. This is the general character of the strata all over the Staked Plains.—J. C. English, county surveyor, Miami, Tex.

Ward County (at Quito).—Well bored by P. G. Durack. Layers of a magnificent red sandstone, from 9 to 12 feet thick, with a half inch of soft lime rock between the layers for 100 feet. Then a cold chilled steel anvil, or some black substance equally hard, on which the drill danced seven days before getting through 6 inches. Then red sandstone 40 feet. Then excellent water in abundance.

Roberts County.—Walter Scoggan, Canadian, Tex.:

"There are several strata of igneous rock from 1 to 50 feet deep. The top one is about 50 feet below the surface of the plain. It is called the rim rock, and there are one or two between that and the bed of Canadian River."

Val Verde County.—B. L. Croucher's well, 30 miles north of Del Rio and 10 miles from Devil's River. Altitude 600 feet above Del Rio.

	Feet.
Light brown soil	5
Clay and gravel	22
White lime rock	340
Soapstone	21
Blue lime rock	70
Clay and gravel	17

B. N. White's well, 20 miles north of Del Rio and 12 miles from Devil's River:

	Feet.
White lime rock	290
Clay and gravel	10

Mitchell County, Iatan Valley.—D. A. Petty, 3 wells 15 feet deep, on Sec. 40, Bl. 28, town 1 north; 8 feet of water in each well.

Soil, clay, gravel, and sand with water.

All these wells have springs at the bottom and each affords 1 barrel every ten minutes.

Midland County.—M. B. Crauson, Midland, Tex.:

	Feet.
Top soil	4 to 10
Clay subsoil	10 to 15
Lime rock	5 to 20
(In this a limited supply of water. Below this usually sand.)	
Clay	20

Gravel and sand with unlimited supply of water rising 20 to 28 feet.

About 50 miles north of Midland, a large number of animal bones at 50 feet, in the wells. At Monahan's wells in the sand hills, likewise deer horns, elephant teeth, and bones at a depth of 51 feet.

Curtis's well, 7 miles north of Midland:

	Feet.
Top soil	4
Limestone	20
Coarse white gravel and water	6

Hall County.—Top soil porous limestone, gravel, or coarse sand. Water.

Ector County, Odessa, Tex.—Artesian well, boring of Odessa Improvement and Irrigation Company.

Bore, 5 inches; depth, 830 feet; cost $1,500.

	Feet.
Soil	4
Rotten limestone	15
Ledge of concrete	
Sandstone	
Gravel to a depth of	123

Three distinct veins of water, which rose 15 to 20 feet, then red jointed clay to bottom of well. At about 700 feet found change in material. Drillers broke their casing and the work was discontinued. The indications were that water would have been obtained at 1,000 feet.

Common Wells, Ector County.—No two wells have exactly the same stratification, but the following may be accepted as the rule:

Surface soil, soft limestone with thin, hard layer at the bottom 30 feet; then hard conglomerate cemented gravel, flint-like material 3 feet.

Water in sand stone or pack sand, below this a soft sandstone with more water. Veins or crevices are occasionally found but usually it is sheet water. Between the surface and a depth of 125 feet from 6 to 7 distinct layers of sheet water are found.

Andrews County.—Soil 12 to 20 feet, clay, hard white or bluish stone, conglomerate sand and water.

Howard County.—W. Y. Stewart, well-driller:

"I bored seven or eight wells within a mile of Big Spring, 90 feet deep. All of them had salt water. Lumps of salt came up with the washings. There is a heavy deposit of rock salt in the immediate vicinity of the town of Big Spring."

Crockett County.—Average well. Soil 4 to 10 feet. Hard limestone; yellowish flinty material; water in gravel.

Mitchell County, Colorado Post office.—Salt company's wells; four wells $5\frac{5}{8}$ inches diameter, each 100 feet deep.

	Feet.
Soil	20
Sand rock	80
Fresh water in sand rock, with streak of iron pyrites, at a depth of 130 feet	30
Red joint clay	60

White sand and pure water. No rise. Joint clay. At 330 feet small quantity of bitter water. At 305 feet one-half inch layer of coal. Joint clay to 500 feet.

Red coarse sand alternating with 4 to 6 inches of salt, 60 feet.

At 560 feet, a bed of salt, 5 feet. Sand rock and red clay to 701 feet. Solid body of salt to 811 feet. Soft red sand rock and red clay to a depth of 936 feet.

At this depth fresh water that rises to within 140 feet of the top. Boring then discontinued. The parties boring the well feel satisfied that 500 feet more will bring fresh water to the surface. All four wells are the same as to stratification, are bored 100 feet apart, and are exactly in line, so that they can, if necessary, be pumped by a horizontal shaft.

Howard County, Big Spring.—County artesian well; cost, $4,000; depth, 603 feet; diameter, 7-inch, 280 feet, 5-inch and 3-inch at bottom.

Gravel, joint clay, very hard rock 200 to 300 feet, gravel, limestone, gravel. At 300 feet salt water; below this, fresh water.

The last water was in soft, porous sand rock, which was penetrated 50 feet. First water at 40 feet.

The water now stands within 4 feet of the surface, but is so salty that it can not be used for any purpose. It is the general impression that the casing was imperfect, and that the bottom water is good. Altitude at mouth of well, by barometer, 2,300 feet. Well abandoned because appropriation was expended.

DISTRICT NO. 1.—SUBHUMID REGION.

FLOWING ARTESIAN WELLS, COMMON WELLS, LAKES, STORAGE RESERVOIRS, AND OTHER WATERS USED FOR IRRIGATION.

In another part of this report, under the head of artesian pumping wells, there is an inclination on part of the water in most wells to rise above the point where it is struck. Fully one-half, or possibly three-fourths, of the bored and dug wells have this feature, and are, as a matter of fact, artesian wells, though they do not overflow. It may be safely said that if they were properly used one-half of them would furnish water enough to irrigate small areas of land, say 5 to 10 or 15 acres each. The rainfall of the east half of District No. 1 is ample and sufficient to mature crops, but the yield may be considerably reduced by occasional dry spells, lasting just long enough to do some injury, but never ruining a crop. The equivalent of a 3-inch rainfall applied during the season two or three times would be ample and sufficient and insure a full crop. A 3-inch irrigation per acre would equal 71,462 gallons. An ordinary 12-foot windmill, pumping 1,000 gallons per hour, or $16\frac{2}{3}$ gallons per minute, would supply the water for 1 acre in three days.

Archer County.—Irrigation necessary half the time at least for full development of crops. Rainfall fairly good October to June.

Atascosa County.—Nic Benntzer, Pleasanton: "Irrigation not always necessary." Average rainfall about 35 inches in fall, winter, and early spring months.

Bandera County.—William S. Ross, Hondo Cañon: "If we only had the seasons (Texas vernacular for rainfall) we could make fine crops here." Rainfall fairly good. In twenty years only three partial failures in the corn crop. Ordinary wells from 20 to 50 feet deep.

Bastrop County.—B. P. Templeton, Garfield: "Average rainfall about 16½ inches between April and September. Irrigation necessary about one year out of every three."

Bee County.—An abundance of good water from 30 to 100 feet under the surface. Mostly used for live stock. Two hundred and two farms in the county.

Bexar County.—F. M. Rowe, San Antonio: "Plenty of rain two years out of three." Caroline Kampman: "Artesian well used for irrigating, stock, and general purposes. Effect of artesian water on vegetation is good." Gardens are irrigated from San Antonio River.

Blanco County.—Carl Goeth, Cypress Mill: "Have plenty of rain this year. Irrigation necessary when corn is in tassel." Rainfall 25 to 30 inches in autumn, winter, and spring. Early planting indispensable to secure uniformly good results in agriculture." Texas State Report, 1882.

Bosque County.—About 150 artesian wells in county, average depth 500 feet, costing about $1.25 per foot; many much less. Average flow about 18 gallons per minute. One day's flow would cover 143 acres 1 inch deep in one day. Several flow over 100 gallons per minute, but a considerable number less than 10 gallons. Allowing the equivalent of 9 inches of rainfall per acre the whole number during the year could irrigate 5,889 acres, or an average irrigating capacity of 39 acres to each of the 150 wells. As the water would be used only during the summer months about half the flow could be utilized and it would therefore be safe to figure on, say 15, to 18 acres as the capacity of an artesian well flowing 18 gallons per minute.

S. H. Lumpkin, Meridian, Tex: "Average capacity of his well about 10 acres (45 gallons flow per minute). Rains usually in winter and early spring. About 1 inch rainfall between April and September."

Citizens well at Meridian, flow 24 gallons per minute, is estimated as capable of irrigating 5 acres. Water used for general purposes. Dr. J. J. Lumpkins' well flows 45 gallons per minute, is estimated sufficient for 3 acres. Effect on vegetation good.

Public well at Iredell, 28 gallons per minute, deemed sufficient for 2 acres. Irrigation necessary in July and August.

Three artesian wells at Kopperl used for family, stock, and gardens. At Morgan, about 20 gallons per minute, used for domestic purposes and flower gardens, irrigates 4 or 5 acres; effect of water is beneficial. If stored the same well could irrigate 75 to 100 acres, according to opinion of Mr. T. F. Lockett, of Morgan. Rainfall about 27 inches, of which about 10 inches fall between April and September. By present methods of farms $8 to $15 is made net on cultivated lands. By irrigation two crops, $50 to $100 net, could be made every year.

Note.—This county is exceptionally well favored in the matter of water supply. Artesian wells can be had in almost any part of the county at a cost of $300 to $700. Ordinary wells are shallow, with an abundance of good water. The streams are nearly all permanent and the county affords hundreds of locations where reservoirs could be built at a trifling expense. The people fully appreciate the value of irrigation but do not understand its application, and hence only a few gardens are irrigated where there should be thousands of acres.

Burnet County.—J. M. Kincaid, Oakalla, Tex.: "Artesian well, 50 gallons per minute, estimated by owner capable of irrigating from 250 to 500 acres. Rainfall between April and September very scant, but irrigating is necessary every year during the cropping season.

Louis Polk, county surveyor: "No artesian wells in county; mountainous section abundantly supplied with springs; water on table-lands found by boring at from 80 to 250 feet, but water does not rise to surface owing principally to caves in the ground, to which water rises and then flows off."

Texas State Report 1882: "The rainfall while not deficient in quantity (averaging 34 inches) is occasionally too scant in late spring and summer for the full development of such crops as mature during those seasons, but wheat, oats, and barley rarely or never suffer from drought. So of the several kinds of midsummer vegetables, irrigation has been found to be advantageous and is beginning to be resorted to with the most beneficial results."

Callahan County.—D. Richardson, Baird, Tex: "There is a sand flat between Clyde and Baird through which the railroad passes at an elevation of about 1,750 feet above sea level, where there are at least 1,000 acres from which no surface drainage ever flows. The railroad made an opening under the track to drain this flat, but no water ever passed through it. We had at one time in May, 1890, 4 inches rainfall in twelve hours, and all went down in this sand flat. We think at some point below this flat an artesian well could be had with a good flow. One-fourth mile east of this flat railroad hands dug a 15-foot well that gave water ample for 100 men and 50 horses.

This flat is more elevated than the country around, and is at the head of the Deadman Creek, flowing northwesterly."

E. E. Solomon, Baird, Tex: "The rainfall during cropping season between April and September was, in 1887, about 18 inches; 1888 about 19 inches, 1889 about 18½ inches. Irrigation would be necessary for development of a full crop every year."

J. B. Norton, Cottonwood Post Office: "At this place (Cottonwood) there is an abundance of good water at from 4 to 20 feet, which in my opinion can be used for irrigating purposes, owing to the vast amount of it so shallow. There never has been any attempt made for artesian water. There is a steam mill and gin here, that is supplied with water from a well 4 feet in depth which can not be drawn empty, and a number of others as strong."

NOTES.—A subirrigated farm owned by J. W. Maltby, 7 miles southeast of Baird, is located at the mouth of a ravine draining several miles of country above. The soil of the farm is a loose, porous, sandy loam, with a gravelly subsoil. The drainage of the ravine passes under this and affords a most abundant supply of water. One or two dug wells on the farm are from 5 to 8 feet deep. The farm has never been irrigated from the surface, but at all years grows magnificent crops, among them the finest of fruits and European grapes.

NOTE.—Within a radius of 3 miles from Clyde (altitude 2,070 feet) there are about 48 wells varying from 25 to 30 feet in depth, costing on an average from $18 to $20. No windmills are used and no one irrigates, but nevertheless at some time each year water could be used to great advantage. On most farms a storage reservoir could be cheaply built. The railroad well at Clyde furnishes from 10,000 to 15,000 gallons daily. It is a dug well 16 by 16 feet and 44 feet deep, the excavation being carried below the water stratum. A boring was made 400 feet below the bottom, but no additional supply was secured.

In Callahan County generally there is fine water in the post-oak timber lands, which are generally sandy and underlaid with water proof clay. The water in the sands is always soft. In a few wells on the upland prairies the water is hard. At Baird, altitude (barometer) 1,850 feet, the water obtained in wells 30 feet deep is salty or mixed with other minerals making it unfit for use. The time when water could be used to best advantage for irrigation is in the months of March and April and again in July and August.

Caldwell County.—Mean annual rain.fall 36 inches, falling in fall, winter, and early spring. Very scant in midsummer and crops often cut short in yield. Common wells 10 to 20 feet deep and good water in abundance. Good springs are numerous in places. The San Marcos River would also afford water for a very large acreage. No lands irrigated at present.

Clay County.—James F. Carter, Henrietta: "Rainfall between April and September from 3 to 5 inches. Irrigation not necessary every year. Rain is getting to be more plentiful. Annual rainfall 28 inches. Mrs. Rachel D. Ivie, Myrtle P. O.: "In this part of the county there are a number of good springs. Soft water in abundance is got at from 12 to 50 feet." Average depth of wells 25 feet. (Texas State Report, 1882.)

Coleman County.—L. L. Shields, Trickham P. O.: "The only flowing well in the county is 220 feet deep and flows salt water and oil. The water is only used as a medical wash and salve." Ordinary wells of good water are obtained at a depth of from 15 to 50 feet. According to the register of the United States military telegraph office at Coleman City, the rainfall for the year 1880, considered about an average with the five preceding years, was as follows: January, 2.03 inches; February, 2.01; March, 3.69; April, 2.18; May, 4.43; June, 4.33; July, 3.13; August, 1.78; September, 7.05; October, 1.78; November, 1.46; December, 1.96; total, 35.83 inches." (Texas State Report, 1882.) No one irrigates, but there is no doubt but that the prosperity of the farmer could be greatly increased if he did.

Comanche County.—"The mean annual rainfall is 26.90 inches, and for wheat and other crops maturing in early spring is always ample, but occasionally is too scant to assure late summer crops. Pure freestone water is secured from springs, which are numerous, and from wells, the latter being easily obtained at from 30 to 40 feet in all portions of the county." (Texas State Report, 1882.)

Concho County.—John M. Pruitt, postmaster, Vigo, Tex.: "On nearly all the stock pastures there are bored wells with pumps and windmills. These wells are occasionally used for irrigation of gardens in addition to supplying water for stock. The bored depth ranges from 60 to 240 feet, according to altitude of location. M. R. Scudder, of Vigo, has a well on the 'Divide' of the San Saba and Concho, which he uses for irrigation to a small extent. There are two small farms near the head of Kickapoo Creek that are irrigated from the waters of the creek, but the stream does not afford water sufficient to irrigate much land. There are thousands of acres lying around me that can not be surpassed in richness. If the artesian well system was applied to these lands there is no figuring on the results. The writer is of the opinion that this system and none other would increase the amount of rainfall just in proportion

to amount of water brought to the surface." "Annual rainfall, 25.04, at Port Concho, 16 miles west." (Texas State Report, 1882.)

Cooke County.—Reuben Perkins, Callisburgh P. O.: "In this immediate vicinity water in abundance at 20 to 40 feet. The rainfall is generally sufficient to mature reasonable crops." Mean annual rainfall 38 inches, and droughts sufficiently protracted to damage crops are infrequent. (State Report, 1882.)

Coryell County.—W. H. Belcher, Pidcock Ranch P. O.: "In Cowhouse Valley, through which runs a small river, part in Hamilton County and part in Coryell County, are about fifty flowing wells. One well flows 50 gallons per minute and is about 320 feet deep. The other wells all stop at the first stratum of flowing water. I believe if the wells were a hundred feet deeper that they would all run from 50 to 75 gallons per minute. These wells are all mineral water that has never been analyzed. None of these wells have more than 30 feet casing, and I expect there is great waste of water through the strata in the rocks. These wells can be drilled here now for $200. Mine was the first and drilled by insurance. Its depth is 290 feet; cost $500; capacity 2½ gallons per minute, and is used for household purposes, live stock, and for irrigating a small garden, and is good for beets, potatoes, cabbage, corn, tomatoes, etc. It could be stored, but is not." Altitude, 2,500 feet; rainfall, about 30 or 35 inches. "J. T. Meeks well, 252 feet deep, cost $200." L. McCloskey, King P. O.: "Well 240 feet deep; cost $240; flow, 2 gallons per minute; used for household purposes and live stock. No good on vegetation." J. M. Davidson, Pecan Grove: "Flowing well, 220 feet deep; cost $233.60. Flows ⅛-inch stream, soda and sulphur, good for family use, watering stock, and irrigating one-fourth acre of garden. Affects fine vegetables. Flowing wells are from 130 to 600 feet deep, and a beautiful showing for irrigation. Many wells in this community already." C. L. Graves, Gatesville, Tex.: "Six or seven wells near Gatesville, 500 to 550 feet deep, flowing from 2 to 20 gallons per minute. Annual rainfall about 33 inches, of which 20 inches fall between April and September."

Denton County.—Four flowing wells in town—flowing from 8 to 10 gallons per minute—and a large number in the County. Denton P. O., from 175 to 600 feet deep. None of the water is used for irrigation. Rainfall, 33.90 for 1880. Common wells 16 to 14 feet deep.

Dewitt County.—Three artesian flowing wells in county, 64 feet deep, flowing 7 to 8 gallons per minute, and used for live stock. "Water supply in county abundant. Ordinary wells 20 to 40 feet deep. The mean annual rainfall is 36 inches, and, as a rule, fairly well distributed throughout the year, but late crops sometimes suffer from drouth." (State Report, 1882.)

Dimmit County.—S. D. Frazier, Carrizo Springs post office: Flowing well at 165 feet; cost, $330; flows about 40 gallons per minute. Used for domestic purposes and irrigation of 4 acres. Its irrigating capacity is estimated at 20 acres. The water appears to have the same effect as rains. Irrigation necessary about three years out of five." Good pure water in ordinary wells is 25 to 50 feet below the surface. The mean annual rainfall of 24 inches is irregular and unevenly distributed through the year, and irrigation is necessary to assure uniform crops. (State Report, 1882.)

Eastland County.—All the common wells bored or dug in the vicinity of the towns of Eastland and Cisco, varying in depth from 20 to 70 feet, are either salty or brackish, the water nearest the surface being the best. All the residents depend on cisterns for their domestic water supply. Near the center of the county good water is obtainable at a shallow depth, but these wells dry out in time of drouth. In the Sandy Creek neighborhood, about 2½ miles northwest from Cisco, are several wells 18 feet deep, affording a good supply of water, and Mr. G. W. Pearce irrigates his garden from one of these wells. The railroad dug a well in the same neighborhood 14 by 14 feet 65 feet deep, but secured no water. A boring of 200 feet was then made in the dug portion and the water rose within 12 feet of the top of the dug well. As the water seems to contain an excess of soda the well was abandoned.

Beginning southwest from Cisco and thence to Cottonwood post office in Callahan County, about 20 miles distant and extending south and west from that point about 15 miles in either direction, is a region in which water in the greatest abundance is found within 3 to 40 feet from the surface. Most of these wells have excellent soft water, though a few are brackish. Nearly every one of these wells held its own during the drouth of 1886. On the Texas Central right of way, about 4 miles southeast from Cisco, the railway bored 400 feet with a diamond drill while prospecting for coal. At 40 feet a good supply of fresh water was found, but it seems that no more was found below that point.

The mean annual rainfall is 27 inches and is usually distributed more favorably for fall, winter, and spring crops than those maturing in summer. The following observations will apply to Eastland, Callahan, Palo Pinto, Stephens, Parker, Shackelford and a number of adjoining counties in which coal indications are more or less numerous, and in which there is post-oak timber.

Considerable areas in all of these counties are of a clayey nature sufficiently tena-

cious to quickly shed water. Only a small proportion of the rainfall is retained in this class of land, and in consequence much more water must be supplied these lands than to the sandy loams common in the same country. These loams generally lie on the clay and hold water to a remarkable degree, producing during the drouth of 1886 fair crops of cotton and corn, while on the clay lands, thousand of oak trees that had attained a growth of 12 inches diameter died. The sandy lands are virtual reservoirs of water, are generally smooth, and have very few water courses, as they seem to retain all the rains that fall on them. The clay lands, on the contrary, are full of water channels and ravines, and during heavy rains shed the greater part of the water falling on them. The ravines and other water courses become raging torrents, which are poured on the lower-lying lands and cause tremendous damage there, while the rain that caused it has done but little good where it fell. Owing to the tremendous "wash" of these torrents, there are thousands of places where water can be stored to advantage, in bodies covering one-half of an acre to 20 acres. There are very few farms in the clay lands, where a few days' work would not build a good reservoir. Part of the crop is lost nearly every year, when practically there is no excuse for it. As irrigation will only be needed in June, July, and August, a reservoir or tank 1 acre in extent and 5 feet deep, will readily supply all the water needed for 40 to 60 acres of corn or cotton. The clay soils, when built into "tanks," will hold water like a jug, and the only loss will be by evaporation. On a good many farms a "tank" can be built on the upper end of the farm, but where this is not practicable, it can be built on the lower end and pumped to a second tank on the upper end, thus:

Quite a number of reservoirs have been built since 1886 for stock water, and these hold water all year. The people realize the value of irrigation, and would apply it if they knew how. They admit that they can have all the water they want if they store it; and they admit, further, that if every farmer and stockman in these counties would build a tank or reservoir, that they could completely change the climate. They would have good water in their wells, have thousands of springs, have running water in their creeks all year, and, above all, would have rains when they need them, as the evaporation from thousands of bodies of water could not fail to provoke rain, where a hot, dry soil would not have such effect.

I have devoted considerable space to the matter of storage reservoirs for the reason that, first, what water there is in the sandy tracts is needed for local, domestic, and stock use. If there is any over for irrigation it will be used there. I doubt that a larger supply will be obtained below. On the clay lands common dug wells run into salt and soda after going down 20 to 70 feet from the surface. The flowing wells at Gordon, and the other borings at Eastland, Cisco, Albany, Baird, Trickham, and Waldrip show salt present at a depth of 200 to 1,600 feet. If good water is found in artesian wells it will be at such a depth as to make it unprofitable for agricultural purposes, unless a very large flow, say a 1,000 gallons per minute is secured. Under the circumstances, I see no other efficient way of securing water for irrigation than by the irrigation storage "tank" or reservoir.

Erath County.—There are a large number of flowing wells on Paluxy Creek, varying in depth from 120 feet to 800 feet, in cost from $100 to $1,500, and in flow from 20 gallons to 200 gallons per minute. I could not ascertain the correct number, as different persons stated varying numbers from 25 to 175. The wells seem to be confined to the valley of the Paluxy and a few of its branches, increasing in depth the farther up stream the borings are made. Here, as in Hood County, the newer borings

on the lower levels show a tendency to rob the upper wells where there is a number close together.

The rule applies here as in the other artesian districts, that the deeper the boring is made the stronger the flow. There are also a great many pumping artesian wells in the county; these are in the vicinity of Stephensville and some of them are 200 feet deep. The water is raised by windmills but is very abundant, as there seems to be an immense storage reservoir under pressure beneath. This also applies to wells in the vicinity of Skipper's Gap. Along the north line of the county salt and sulphur water are found at a depth of 960 feet, as shown by the flowing well at Thurber, a coal-mining town. It seems to be the rule here as in Palo Pinto, Eastland, and Callahan counties, that wherever there are indications of coal good water can be only found at great depth. All the artesian waters in this county except the Thurber well are beneficial to plant life. Hon. J. L. Humphries, county judge, resident at Bluff Dale, thinks that strong flows could be had most anywhere in the county by going deep enough, say 1,000 feet to 2,000 feet. The annual rainfall is 27 inches, sufficiently irregular to occasion some loss almost every year, but very rarely resulting in total failure. One or two irrigations, equal to a 3-inch rainfall, applied in June and July, would in all probability secure perfect crops nearly every year. This water can be readily supplied by the artesian wells, common wells, and dirt storage reservoirs.

Frio County—Three artesian wells have been bored in this county varying in depth from 158 feet to 391 feet and in cost from $273 to $910. Flow varies between 3½ to 8½ gallons per minute. The water appears to be beneficial to plant life, and the wells are used for irrigation of about 3 acres each. The mean annual rainfall at Castroville, 20 miles from the north boundary of the county, is 22.45 inches. Drinking water is obtained from wells of moderate depth in nearly all parts of the county.

Gillespie County (altitude 1,700 feet).—Rainfall 28 inches. Wells shallow and springs numerous.

Gonzales County.—Dr. J. K. P. Green's flowing well, 130 feet deep, cost $400—flow 3 gallons per minute, used for general purposes and irrigating garden. J. M. York's well, 192 feet deep, flow 3½ gallons per minute. James Been's well, 216 feet deep, 5 gallons per minute, water in all three soft and clear. Ordinary wells of moderate depth, but many cisterns used. Annual rainfall about 38 inches; generally well distributed, though late summer crops are sometimes injured by drought.

Goliad County.—Hy Shaper, county judge, owns two flowing wells each 60 feet deep flowing 10 gallons per minute; not used for irrigation. Annual rainfall about 35 inches. Ordinary wells of moderate depth.

Grayson County.—Four artesian flowing wells near Pottsborough, not used for any purpose. Ordinary rainfall 39.94 inches, and often in excess. No irrigation practiced in county which is a fine fruit growing region.

Tom Green County.—H. C. Sweet, Mangum, Tex., "Water is obtained in ordinary wells in from 12 to 40 feet all over the county."

Hardeman County.—Rainfall principally in fall and spring, very little in mid summer. Irrigation not necessary for wheat and oats, but would greatly benefit corn. Have not observed rainfall closely but think 12 inches fall between April and September.

Haskell County.—A. C. Foster, Haskell: "Irrigation would assist 50 per cent.

Hays.—Mean annual rainfall above 30 inches. Ordinary wells of shallow depth. No flowing wells.

Hill County.—(J. O. Files). In this vicinity there is a number of flowing wells. There is one here at this place 250 feet deep; the water stands 150 in same, bore 6 inches in diameter. The supply is considerable, and has never been tested. A windmill is used for elevating the water, and has never been exhausted. The water is very soft; in all of these deep wells there seems to be slight traces of sulphur, but not unpleasant to the taste.

We have what we call surface water which we strike in digging from 10 to 40 feet, and affords an abundance of water for general purposes, and it might be used for irrigation purposes to good advantage. We have also springs that have never been known to fail.

Artesian water could be obtained anywhere in my vicinity by going deep enough, and, as a general rule, the deeper, the stronger the flow. The kind of water storage, that we usually have is dirt thrown across ravines, which after catching full hold through the dry season, and have been used only for watering of stock. The system of irrigation has never been tried here. For the last few years we have had sufficient rainfall to answer all crop purposes, though this country is subject to drought; then irrigation might be used to great profit. There are great numbers of bored wells within a radius, say, of 10 miles. Itasca, a town on the M. K. and T. R. R., 6 miles west of here, is its principal water source. It has dozens of such wells, and windmills are extensively used for raising the water. One well of this kind supplies the business portion of the place. I suppose if the water was properly used it might irrigate 8 or 10 acres of land. No flowing wells in the neighborhood of Itasca; the

nearest are the wells in Files Valley, and all bored wells in the valley do not flow. The one I mention, to wit, 250, is deeper than the wells that have a good flow.

Hood County.—A great number of artesian wells along Paluxy Creek, some of which are used for irrigating gardens. The flow varies from 10 gallons to 50 gallons per minute, the depth from 236 to 500 feet, and the cost from $250 to $500. Irrigation considered necessary at times, though crops are made every year. "Tanks" or artificial ponds for stock are quite numerous away from the streams. The annual rainfall is 36 inches, generally sufficient in fall and winter, but sometimes deficient in summer. Ordinary wells are of moderate depth.

Isaac Moore reports: "There are a good many artesian wells in this section. Some rise 20 feet above the surface. All go through blue dirt and red marl before they strike water. I have a well 201 feet deep, 3-inch flow; water good for all purposes; irrigate a garden, and if all the water was saved could irrigate 16 acres."

Jack County.—Two flowing wells, 7 miles west of Jacksborough, 96 feet and 130 feet deep. Mean annual rainfall, 26.23. Irrigation deemed necessary about one year in three, according to opinion of Mr. O. Jasper, Jacksborough, Tex.

Johnson County.—James A. Drennan, Equestria post office: "Rainfall between April and September between 7 and 9 inches. Irrigation necessary from 15th of June to September 1."

Mean annual rainfall, 24 inches, falling mainly in winter, spring, and early summer; sometimes scant in midsummer. Good wells are easily obtained. Texas State Report, 1882.

Karnes County, Skiles post office.—"There are no artesian wells in this section. Several bored wells; water obtained at from 120 to 200 feet. Some very good, some salty. Artesian wells could no doubt be had by boring at from 500 to 900 feet."

Annual rainfall, 35 inches; most abundant in fall, winter, and spring, and often too scant in summer for late crops. State Report, 1882

Kerr County.—Japonica. Ann E. Joy: "A. E. Burgo, A. H. Cox, W. R. Bean, J. Vining, L. S. Hatch, A. J. Merrett, and others have bored wells, not artesian, ranging in cost from $300 to $500; used for watering stock. The water is raised by windmills, and is said to be good for watering crops."

Irrigation does not seem necessary every year, but is needed for vegetables, unless the season is very wet. Those that live on the water courses have lasting water all the time; on the "divide" they use wells and windmills. Altitude, 1,650 feet. Rainfall, 29 inches; greatest fall in April, May, June, August, and September.

Kimble County.—Frank Vickrey, county surveyor: "Irrigation necessary more or less every year."

Mean annual rainfall 24.90 inches, but is not usually so distributed as to insure spring and summer crops, for which irrigation is necessary and could be cheaply obtained on many of the streams. Texas Report, 1882.

Lampasas County.—The mean annual rainfall is above 32 inches, and is usually sufficient for all fall, winter, and spring crops, but in late summer is sometimes scanty, though most crops are reasonably sure without the aid of irrigation. General altitude about 1,200 feet. Texas State Report, 1882.

La Salle County.—A flowing artesian mineral well at Cotulla. Common wells easily obtained, though much water for live stock is collected in storage "tanks" or dirt reservoirs. Mean annual rainfall is 23 inches, but is not so distributed as to insure late crops, which frequently suffer from drought. Farming as a distinct pursuit is not followed, the only land tilled being small patches attached to stock ranches. The annual rainf ll in the vicinity of the Cotulla flowing well (reported elsewhere) is stated to be about 16 to 20 inches; during cropping season, April to September, from 2 to 10 inches; irrigation needed three out of five years.

Llano County.—The mean annual rainfall is 24.90 inches. Late summer crops sometimes require irrigation, for which the facilities are ample and convenient along the several streams, and to a limited extent near some of the springs.

McCulloch County.—J. L. Spiller, Voca postoffice: "Irrigation is necessary every year. Some bored wells here. They cost $1.25 to $1.50 per foot; others cost $3 per foot. All are in solid sand rock 25 to 75 feet. One in town here is 85 feet deep. I suppose it could be used for irrigation, though it would be very expensive. No artesian wells in this vicinity."

There are two bored wells near Waldrip, bored by coal prospectors, which are used for stock. The water is too salty for purposes of irrigation. The annual rainfall is 24.90 inches, and it is believed to have gradually increased in quantity as well as regularity of distribution within the past decade. Altitude about 1,200 feet. (Texas State Report, 1882.)

Menard County.—F. M. Kitchens, Menardville. "Rainfall in the county very irregular, and irrigation is necessary every year."

Deep borings for water result in the finding of sour and salty water; that is, at 150 feet sour water and at 450 feet oil and salt water, though Mr. K. thinks fresh was struck at 800 feet. Shallower borings seem to afford good water.

"The mean annual rainfall, as registered at Fort McKavett, was, for the year 1878, 21.88 inches; 1879, 16.65 inches; 1880, 28.61 inches; 1881, 21.72 inches, the highest mean monthly precipitation being in July, August, and October. In an article prepared for the editor of the Texas Almanac for 1867, by Hon. James E. Bruck, at that time representative in the State legislature, the fact is stated that near the center of the county, on the San Saba River, are found the remains of an ancient mission, or presidio, believed to have been occupied a hundred years or more ago, and near it are unmistakable evidences that many thousand acres of the valley were at one time in cultivation, by systematic irrigation, and that wheat was the product chiefly grown." (Texas State Report, 1882.)

McLennan County.—At Waco are the strongest flowing wells in the State. There are five altogether. Four of them are owned by the Bell-Moore Water Company of Waco. Of these the largest has a bore of 8 inches and a depth of 1,852 feet; another well has a bore of 5⅝ inches, and the two remaining ones have a bore of 4½ inches and a depth of 1,834 feet. The cost of the largest well is given at $7,200, that of the 5⅝-inch well at $5,000. The two 4½-inch wells probably cost each about the same, as they were all intended for 8-inch wells, and the reduction of bore was due to accident. This would equal an expenditure of about $22,200 for the four wells, to which might be added the cost of four other borings which resulted in failures.

The Waco Water and Power Company's well has a depth of 1,812 feet. Its cost is not known but can be estimated at $6,500, if not more. Assuming these figures to be approximately correct (though the same work can now be done for much less money since the drillers now thoroughly understand the nature of the material they penetrate), the cost of the five wells, exclusive of cost of former experiments, of stand pipes, water mains, storage reservoirs, hydrants, etc., would be $28,700. The advertised capacity (daily output) of the Bell-Moore wells is 3,800,000 gallons, and of the Water and Power Company's well is 1,200,000 gallons, aggregating daily 5,000,000 gallons. None of the wells are used for purposes of irrigation barring the sprinkling of lawns and the watering of flower gardens. From an agricultural point of view these wells are in the wrong place. The annual rainfall about Waco is, according to the report of the commissioner of statistics of Texas for 1882, 39 inches; the seasons are generally regular and protracted droughts are of rare occurrence. The wells constitute the water supply of a city of fair size.

If these wells were situated on the Texas Staked Plain, where they could count as a factor in irrigation, they would prevent the following possibilities: The rainfall of the Staked Plain varies between 18 and 30 inches, falling mainly between the 21st of April and the 15th of September, apparently at precisely the right time to perfectly mature crops. But this is not the case, as the rain comes in tremendous showers at comparatively long intervals and without regularity. Some locality will receive fine local showers at short intervals, while some other point not 30 miles distant will alternately have a deluge or a drought. Now, taking 18 inches as the minimum quantity of rainfall any locality on the Staked Plain and Panhandle is likely to receive, it would be safe to allow a maximum quantity of irrigation water, equaling a rainfall of 18 inches, to be supplied artificially. This would give that section of country the equivalent of a 36-inch rainfall, distributed just at such times when needed, securing a perfect crop in every sense of the word, which means from 40 to 50 bushels of wheat and from 90 to 120 bushels of oats and from 1 to 2 bales of cotton per acre. The driest time on the plains is from the middle of September to the 21st of April, and two-thirds of the artificial water will have to be supplied during that time.

Supposing the five Waco wells to be situated on the plains, there would be available 5,000,000 gallons, or 1,825,000,000 gallons in one year. Each acre that is to receive its full share will be entitled during the year to 488,772 gallons, the equivalent of 18 inches of rainfall; 3,734 acres could then receive their supply from these five wells during the year. Divided into 40-acre farms there would be 93 and a fraction. To successfully irrigate these each farm would require a small storage reservoir, circular, 66 feet diameter and 6½ feet deep, which would be filled three times during the year; four irrigations of 4½ inches each would be more than enough. The cost of the wells at Waco is about $28,700. Say that, if the water were known to be present, a flow of 5,000,000 gallons daily could be secured on the Staked Plains at $30,000, the investment would pan out about as follows: Divide the cost of the flumes and ditches necessary to reach each farm among the acres to be irrigated. This may amount to $10, $20 or $50 per acre. The cost, whatever it is, constitutes the value of the water right, which probably will not exceed $10 to $15 per acre. The use of the water ought to be worth $2 per acre, though it can be furnished for $1 per acre. Figuring at $2 per acre, the annual income will be $7,448, or about 24.8 per cent. on the money invested. The cost of the supply per acre will be about $8.03. It is evident from the foregoing that artesian wells, if strong enough in flow, will pay, and that it will pay at depth of 1,850 feet. In fact wells from 2,500 to 3,000 feet will pay if the water is there, but under present conditions private capital can not be obtained for the purpose of ascertaining this fact; but once assured that the water is there, I believe

that an unlimited amount of money could be obtained for the boring of such wells.

Maverick County.—W. A. Fitch, Eagle Pass: Artesian well under construction, 1,140 feet deep. Salt water at 360 feet and at 525 feet; gas at 580 feet. Mean annual rainfall 13.06 inches.

Montague County.—J. H. Wolson, Sunset: "No artesian wells. An excess of rain during the past month; need no irrigation. All wells in these parts are bored from 40 to 120 feet deep. Excellent water, slightly limestone. An abundance of water found in gravel and quicksand, but all on a general level. There is a mineral well at this town."

"Wells of good water can be obtained in all parts of the county at an average depth of 35 feet. The mean annual rainfall is 30.23 inches, and is usually so distributed that protracted droughts are uncommon. (State Reports, 1882.)

Palo Pinto County, Gordon.—There are three flowing wells at and near Gordon, varying in depth from 488 to 498 feet, costing from $500 to $800. The water obtained contains salt and gas, and is unfit for purposes of irrigation. Mr. G. W. Cotney, of Gordon, thinks that the last water obtained was fresh, and that by the use of proper casing good water might have been received. The flow from these wells is only about a gallon per minute. There are no common dug or bored wells at Gordon, as salt water is found: the same applies also to Santo Station, 11 miles east. A few miles away from the town and the line of the railroad there are many ordinary wells, varying in depth from 30 to 40 feet, affording an abundant supply of hard lime-water, good for domestic use. The rainfall in the county is 26.23 inches, so distributed as to generally assure fair crops; but in some years the rainfall is very irregular. The county is hilly and affords hundreds of fine locations for storage dams. Water for irrigation can be obtained from wells in some parts of the county, but in others the storage reservoir will have to be relied on. The soils are clayey and will hold water well if used for dams. A little labor and energy displayed by the inhabitants in the work of securing a water supply could make this a very rich county.

Parker County.—There are six or seven flowing wells within a radius of 2 miles of Springtown, and this seems to be the only point in the county where such have been obtained. Water generally is obtained in ordinary wells at a depth of 18 to 40 feet. The rainfall is given as follows: 1878, 31.34 inches; 1879, 23.71; 1881, 23.54 inches; generally sufficient to mature crops every year. The western half of the county is somewhat hilly, and is to a large extent covered with post oak timber. The subsoil in many places is a stiff red clay, and is usually found in such localities where it could be used in the construction of storage "tanks" or reservoirs from 1 to 10 acres in extent. Compared with irrigated lands, the people of this county get a "half crop" from year to year. They could vastly improve on this by using the facilities they have at hand. F. D. Pinkham, at Milsap, writes that ordinary wells in his neighborhood are from 20 to 120 feet deep.

Duval County.—"During the last decade the rainfall has been annually 29.30 inches, and more evenly distributed than formerly. Summer droughts have become less frequent and protracted. Farming is not carried on as a business; cultivated land is only seen in connection with stock ranches and limited to raising vegetables and corn for the rancheros. Wells of pure water are generally obtained at a moderate depth." (Texas Report, 1882.) "There are some wells in the county 250 to 300 feet deep that are operated by wind power or pumping jacks. No Artesian wells in the county."—Jno. J. Dix, county surveyor.

Robertson County.—L. T. Fuller, Calvert: There are a great many flowing wells all through our bottom lands and two in town.

San Saba County.—J. H. Martin, San Saba: The average depth of common wells is from 20 to 30 feet. Many of these dried up in 1886. They then bored 100 feet further and the water then rose to the surface. Water to irrigate 10 or 15 acres can be had on almost any farm. At the present time there are barely 1,000 acres under irrigation, water derived from springs. The water for one farm is pumped from the San Saba River. Farming lands are worth $4 to $10 per acre, and irrigated lands $50 to $100 per acre.

DISTRICT NO. 3.—ARID REGION.

This district comprises all that portion of Texas lying west of the one hundred and third meridian, where it crosses the Pecos River, and south of this river to the Rio Grande, which forms the south boundary. All of this territory adjoins New Mexico on the north. It contains the counties of Brewster, Buchel, El Paso, Jeff Davis, Foley, Pecos, Loving, Presidio, and Ward, comprising in all 31,620 square miles. The altitudes of the district are given as follows:

	Feet.
Texas Pacific Railway:	
Pecos	2,590
Toyah	2,975
Antelope	4,320
Boracho	4,460
Kent	3,900
Carrizo, now Allamore	4,610
Sierra Blanca	4,700
Southern Pacific Railway:	
El Paso	3,713
Ysleta	3,664
Rivera	3,648
San Elizario	3,630
Fabens	3,614
Rio Grande	3,664
Fort Hancock	3,519
Madden	3,668
Finlay	3,945
Malone	4,265
Etholen	4,648
Sierra Blanca	4,512
Grayton	4,227
Torbert	4,343
Dalberg	4,188
Haskell	4,013
Chispa	4,082
Wendell	4,223
Valentine	4,424
Ryan	4,746
Marfa	4,692
Paisano Pass	5,082
Toronto	4,734
Alpine	4,485
Strobel	4,493
Altuda	4,642
Marathon	4,043
Warwick	4,071
Haymond	3,883
Maxon Spring	3,538
Rosenfeld	3,665
Longfellow	3,274
Emerson	3,095
Sanderson	2,780
Eldridge	2,362
Dryden	2,109
Thurston	1,911
Lozier	1,535
Samuels	1,826
Langtry	1,321
Shumla	1,418

The United States Government observations are:

	Feet.
Aroya Escondido	2,115
Fort Bliss	3,830
Comanche Spring	2,874
Fort Davis	4,700
Eagle Spring	4,536
Hueco Pass	5,450
Hueco Tanks	3,935
Leon Spring	2,807
Ojo Escondido	2,311
Pecos Spring	3,098
Presidio del Norte	2,779
Fort Quitman	3,710
Fort Stockton	3,050
North Franklin Mountain	7,069

The annual rainfall as observed at El Paso and at Pecos City, varies between 10 and 17 inches, being precipitated mainly in the months of June, July, and August. The rainfall is very irregular, and agricultural pursuits without irrigation are out of the question. On the mountains the rainfall frequently equals from 10 to 15 inches in a single shower while the lower lying plains or mesas receive less than that during an entire year. Deep well borings have been made in a number of localities, but no artesian water has been found except in the valley of the Pecos River.

Flowing artesian wells at Pecos City, Reeves County.

Owner or informant.	Depth.	Bore.	Cost.	Remarks.
	Feet.	*Inch.*		
J. B. Gibson	250	4	$300	9 gallons per minute.
W. S. Marshall	315	3	500	60 gallons per minute, pressure 20 pounds.
Texas Pacific Railway	220	4	440	Water rises 27 feet above ground.
C. H. Merriman	185	3	351	60 gallons per minute.
W. D. Johnson	185	3	....	Do.
Do	185	6	....	Very light flow.
T. M. Clayton	227	3	....	All these wells are bored within a circumference of 2 miles, and all of them have a continuous flow.
Matherson, Cook & Walker	213	3	....	
Gage, Walthall & Powers	250	3	....	
Pecos Valley Land and Irrigation Company.	237	3	....	
Havens, Phillips & Allen	237	3	....	
Juston Robertson	shallower	2	....	
A. T. Windom	...do	2	....	
W. D. Johnson and C. F. Thomason	235	3	....	
County of Reeves	227	3	....	
Chilton, Bowen, et al	....	3	....	

These wells are located on section 40, H. & G.N. surveys, and section 69, block 4, H. & G. N. The water in all of them is slightly brackish, some being better than others; in one or two some saline ingredients. The water, however, is not injurious to vegetation and in a small way is used for irrigating gardens, though most of it is allowed to run *ad libitum* and make a mud puddle of the vacant town lots.

Flowing artesian wells at Toyah, Reeves County.

Owner or informant.	Depth.	Diameter.	Cost.	Remarks.
	Feet.	*Inches.*		
Texas and Pacific Railway...	834	*9 †3	......	300 gallons per minute, or 432,000 gallons per diem.
Do......................	514	12	....	About 9 gallons per minute. Now being bored down farther.

* Top. † Bottom.

The water from both of these wells is white sulphur with a salty taste, and can be used to advantage for irrigation, as the water does not seem to be injurious.

At Toyah the water is found at 20 to 30 feet. Underneath this, at a depth of about 200 feet, at Pecos, is artesian water under great pressure. Now at Toyah, altitude 2,975, the same water is found at about the same depth and in about the same material, but it is devoid of pressure here. At 832 feet a strong flow (300 gallons per minute) of sulphur water was obtained. (It is claimed that the sulphur came from some higher point in the well and that the bottom water was pure, and that the present outflow is impregnated with sulphur only because the casing was defective.) It is probable that this same water will in all probability be found at Pecos at a similar depth. Adding to the pressure existing at 200 feet, 300 gallons per minute through 3-inch pipe, the weight of a column of 375 (the difference in altitude between Toyah and Pecos) it is easy to presume that at a depth of 1,000 feet artesian wells can be obtained which will flow from 1,000 to 2,000 gallons per minute.

The wells of this subdistrict as a rule are very deep and the water found in many of them is practically unfit for use. Those on the Lanonia Mesa, north of El Paso have been described. A few shallow wells, nine or ten, are in the valley between the Diablo and Carrizo Mountains, and are from 30 to 40 feet deep. Their supply is perhaps sufficient for a few hundred head of cattle, but they will have none to spare for irrigation. Whether or not artesian water can be obtained on the great mesas in El Paso, Presidio, Buchel, and the southern part of Pecos Counties, the authorities differ. Some of the well-drillers claim it can be found and some geologists assert the contrary, with the history of the Southern Pacific and Texas and Pacific Railway wells in their favor. The geologists predicted total failures at Pecos City, and a most abundant flow was secured, not only in one well but in twenty-three. On the other hand, an enterprising well-driller, with more perseverance than discretion, tackled the granite core of Franklin Mountain, north of El Paso, bored 800 feet in granite and left a dry hole. It is asserted that going north of the Franklin Mountains, and east into the valley between the Franklin and Husco Mountains there is a vast underground stream, and that in this valley flowing water could be obtained.

Other deep wells in District No. 3.

Location.	Owner.	Depth.	Diameter.	Cost.	Stage of water from surface.	Remarks.
		Feet.	*Inches.*			
El Paso County: Sierra Blanca....	Texas and Pacific Railway.	1,000	....	$4,500	905	Water strong alkali and brackish, rarely used. Unfit for steam for irrigation, or human use.

No private party could maintain a well here. the depth too great and the cost of raising too much.

Location.	Owner.	Depth.	Diameter.	Cost.	Stage of water from surface.	Remarks.
Torbert..........	Southern Pacific Railway.	1,060	*8 †5	7,300	....	Only a seep of water.
Lanoria Mesa....	Lanoria, Mesa County:					
	No. 2..............	246	....	....	....	
	No. 3..............	262	....	....	....	
	No. 4..............	621	....	....	....	
	No. 5..............	232	....	....	....	
	No. 6..............	210	....	....	....	
	No. 7..............	240	....	....	....	

Wells Nos. 2, 3, 5, 6, and 7 all finished at average of 30 to 35 feet below where water was struck, being in a bed of sand, gravel, and water, which percolates into the pump pipe as fast as it can be pumped. Working the drilling engine on a 3-inch pump can not decrease the supply in the least, which apparently underlies the whole mesa, as one vast lake bed. Water being perfectly pure and soft as per following analysis: 9° temporary hardness, 6° permanent hardness, equivalent to 8 grains carbonates to gallon of water. "Clark's scale." Well No. 4 struck water at 225 feet and continued in water and sand to 534 feet, where a stiffer formation of clay. Cased same off, and in penetrating that the water rose to 65 feet of the surface and afterwards sunk to original level, where it now is, about 215 feet from surface. Work on this well is being continued. Information from Messrs. Newman, Russell, and Cotes, El Paso, Tex.

Location.	Owner.	Depth.	Diameter.	Cost.	Stage of water from surface.	Remarks.
Pecos County: Dryden..........	Pecos Land and Cattle Company.	590	....	11.80	51	Inexhaustible to horse-power or windmill.
Do..........	W. W. Simmonds: "All deep drilled wells 6 to 10 inch drill used. Water rises to about 540 feet of the surface."					
Presidio County: Marfa..........	J. R. Marmion, county surveyor: "A few wells have been bored by individuals to a depth of 150 feet, but none deeper than 200 feet, with good results as to water."					
El Paso County: Finlay..........	Southern Pacific Railway.	1,080	8	....	....	Bad water at 396 feet, and well abandoned.
Sierra Blanca....	....do..............	943	$5\frac{5}{8}$	....	....	Unlimited supply; poor water; pump capacity, 1,800 gallons per hour.
Torbert..........	....do..............	1,100	*8 †$5\frac{5}{8}$	....	....	Small stream; fair water at 696 feet deep. Well abandoned.
Haskell..........	....do..............	2,029	*12 †$7\frac{5}{8}$	....	....	1,500 gallons per hour exhaust well in 3 hours.
Jeff Davis County: Valentine.......	....do..............	1,245	*$5\frac{5}{8}$ †3	....	....	Excellent water. Capacity, 1,200 gallons per hour.
Buchel County: Maxon Springs..	....do..............	1,004	*$9\frac{1}{2}$ †$4\frac{1}{2}$	....	....	Water abundant. Well abandoned.
Pecos County: Longfellow......	....do..............	683	8	....	....	Fair water; 1,250 gallons per hour.
Sanderson.......	....do..............	987	$7\frac{5}{8}$	....	....	Good water; 1,700 gallons per hour.
Dryden..........	....do..............	1,797	*$7\frac{5}{8}$ †4	....	....	Good water; 1,000 gallons per hour.
Lozier..........	....do..............	770	$7\frac{5}{8}$	....	....	1,000 gallons per hour exhausts the well in 2 hours. Fills up again in 2 hours.
El Paso County: Eagle Flat.......	Texas Pacific Railway.	680	....	....	....	At 480 feet struck a cavern 30 inches deep. No water. This well has issuing from it, part of the day, a current of air. The remainder of the day the air is sucked in.

* Top. † Bottom.

Other deep wells in District No. 3—Continued.

Location.	Owner.	Depth.	Diameter.	Cost.	Stage of water from surface.	Remarks.
		Feet.	*Inches.*			
Reeves County, Pecos City: Sixty miles above Pecos and 18 miles from Pecos River a well was bored by C. H. Merriman, 300 feet through red sand rock and clay in alternate layers, with no trace of water from first to last. There is also reported, as bored by him, a well 9 miles west o fcity—depth, 160 feet; plenty of water. Also a well 6 miles south. Went down 318 feet and stopped in white sand rock; water at 15 feet, and at 180 feet struck 80 feet of coarse gravel and pebbles, water rose to 15 feet of top of well. Could not be lowered by pumping.						
El Paso County:						
Fort Hancock....	U. S. Army	275	....	....	....	Water rose to within 7 feet of surface.
Van Horn	Texas Pacific. Four drilled wells, 600 feet deep, 5⅝ inches diameter, 500 feet from top to water-line. The four wells are operated by steam pumps, using 3¾-inch cylinders, and yield each 150 gallons per minute. The cost was $550 each.					

*Top. †Bottom.

Stratification of wells in District No. 3.

El Paso County.—Sierra Blanca, Southern Pacific and Texas and Pacific Railway wells:

	Feet.
No record of strata above	515
Hard red sandstone	515
Very hard white quartz	520
Blue quartz	650
Red granite	687
Soapstone	700
Hard white sand rock	735
Red and white sand rock	748
Red sandstone and white quartz	752
Red and white sandstone	768
Hard quartz	776
Flint	781
Slate and black limestone	792
Sandstone	800
Do	805
Do	810
Sandy red rock	868
Hard sand	885
Dry sand	892
Hard sand	900
Sandstone and water	920
Hard sand	940
Limestone	1,300

Jeff Davis County.—Valentine, Southern Pacific Railroad:

	Feet.
Clay	85
Lime rock	10
Hardpan	295
Sand and water	

El Paso County.—Torbert, Southern Pacific Railway:

	Feet.
Clay	700
Sand and clay mixed	300
Clay	60
	1,060

Pecos County, Dryden.—W. W. Simonds. Nearly all limestone, with some small seashells. Found water at 590 feet in sand and gravel in about a 10-inch vein. Water rose 51 feet and no more. Am using pump and have never been able to exhaust the well.

Reeves County, Pecos City.—C. H. Merriman. White lime and clay, quicksand, blue clay, sand. Concrete of sand 2 to 5 feet, hard and just overflowing water, 225 feet.

A well is reported 6 miles south of Pecos City, depth 318 feet; stopped in white sand rock; plenty of water. Also at 15 feet water was found, and at 180 feet a vein of 80 feet of coarse gravel and pebbles was passed through. Water rose to 15 feet of surface and supply was not lessened by pumping.

In the vicinity of Pecos there is the greatest diversity in the arrangement and thickness of material passed through. No two wells are entirely alike. In several wells a blue mud was found at 120 feet. This is absent in others. Stone of any kind is absent in most wells, excepting a thin shell of lime or gravel concrete or conglomerate.

Reeves County, Toyah.—Texas and Pacific artesian well. Depth, 832 feet; diameter, 9 inches for 400 feet, reduced to 3 inches to botton, 432 feet. At 800 feet sulphur water as black as ink; after this, water in white sand.

Strata: Black dirt, gray and red clay, marl and seashells, gray and red sand rock, 8 feet; sandy soil, 20 or 30 feet; gray sandstone.

At bottom fine white sand. Cased about 700 feet. Test made to ascertain quality of water at the bottom by inserting ¾ pipe down into the white sand. Through this ¾ pipe a much purer water was obtained than from the casing. The flow is a strong white sulphur water, free from alkali or gypsum. Flow, 300 gallons per minute. It is the opinion of Mr. S. M. Field that the water in the white sand is pure and that it is only sulphurous because the casing is defective.

El Paso, Tex., *May* 8, 1890.

Log of wells drilled by Lanoria Mesa Company on the "Lanoria Mesa," about 10 *miles northeast of El Paso. Surface about* 250 *feet above Rio Grande River.*

Strata.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	Remarks.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
Clay	25	10	8	9	12	10	Wells Nos. 2, 3, 5, 6, and 7 are finished at an average of 30 to 35 feet below where water was first struck, being in a bed of sand, gravel, and water, which percolates into the pump pipe as fast as it can be pumped, and working the drilling engine on 3-inch pump pipe can not decrease supply in the least, which apparently underlies the whole mesa as one vast lake bed, water being perfectly pure and soft, as per following analysis: 9 degrees, temporary hardness. 6 degrees, permanent hardness. Equivalent to 8 grains carbonate to gallon water. "Clark's scale" well, No. 4, struck water at 225 feet and continued in water and sand to 534, where a stiffer formation of clay cased same off, and in penetrating that the water there raised to 65 feet of surface and afterwards sunk to original level, where it now is, about 215 feet from surface.
Sand	32	30	45	20	15	28	
Clay	10	15	10	18	60	15	
Sand	28	40	20	30	25	30	
Clay	35	10	15	15	35	22	
Sand	15	25	25	45	14	40	
Clay	20	8	20	10	32	27	
Sand	12	25	15	30	17	36	
Clay	23	15	30	20	......	19	
Sand	25	30	10	35	......	13	
Clay	15	20	22	......	......	......	
Sand	14	8	75	......	......	......	
Clay	......	6	10	......	......	......	
Sand	......	20	40	......	......	......	
Clay	......	......	4	......	......	......	
Sand and gravel	......	......	80	......	......	......	
Clay	......	......	10	......	......	......	
Sand	......	......	60	......	......	......	
Clay	......	......	36	......	......	......	
Sand	......	......	35	......	......	......	
Clay	......	......	15	......	......	......	
Sand	......	......	35	......	......	......	
Sand rock	......	......	1	......	......	......	
Sand	......	......	......	......	......	......	
Finished depth, (except No. 4)	246	262	621	232	210	240	

PRICES PER FOOT PAID FOR WELL BORINGS IN TEXAS.

Archer County.—Drilling, $1.50 per foot; casing, 60 cents; 6-inch casing, 500 feet.

Atascosa County.—Horsepower rigs, $1 first 100 feet, $1.50 second 100 feet; all sizes of bores.

Bexar County.—One dollar and fifty cents first 100 feet, $2 second 100 feet, $2.50 third 100 feet, $3 fourth 100 feet, $3.50 fifth 100 feet.

Bosque County.—Seventy-five cents first 100 feet and 50 cents additional for every additional 100 feet. ———: $1.50 for first 100 feet, $2 for next 200 feet, $2.50 for balance; 6-inch wells 525, 600, and 800 feet. Morgan: Generally $1 per foot, 6-inch bore, 500 feet.

Burnet County.—Oakalla: $1 per foot, 6-inch bore, 100 feet.

Coleman County.—Trickham: $1 per foot, 6-inch bore.

Coryell County.—King: $1 per foot, 6-inch bore, 240 feet. Pecan Grove: 75 cents first 100 feet, $1 second 100 feet; $20 for 26 feet, 6-inch bore.

De Witt County.—Yorktown: $2 per foot, including tubing and casing.

Dimmit County.—Carrizo Springs: $1 first 100 feet, 50 cents additional for every additional 50 feet.

Erath County.—Bluff Dale: $1 for first 100 feet, 25 cents additional for each additional 100 feet; 150 to 800 feet; 75 cents for first 100 feet, $1 for next 100; 165 feet.

Frio County.—One dollar first 150 feet, $1.25 next 100 feet, 25 cents additional every 50 feet; 3 to 6 inch bores; 390 feet.

Gonzales County.—Rancho: $1 to $2.50 at finish; 130 feet.

Grayson County.—Pottsborough: $1.50 first 100 feet, $2 for balance; 250 feet, cost with casing, $3 per foot.

Hardeman County.—Sixty cents per foot, 10-inch wells 100 feet deep.

Hood County.—Paluxy: $1 per foot, 236 feet.

Jack County.—Jacksborough: 75 cents first 100 feet, $1 for second 100 feet, 6-inch bores.

Johnson County.—Cleburne: $1 for first 100 feet, then $3, and lastly $5 per foot.

McLennan County.—Waco: $2 for first 1,500 feet, $3 next 100 feet, $4 next 100, $5 next 100 feet, etc.

Palo Pinto County.—Gordon: $1 first 100 feet, 25 cents per foot for each additional 100 feet.

Parker County.—Weatherford: 75 cents per foot, 440 feet.

Robertson County.—Calvert: $1.25 to 50 feet, $1.50 next 50 feet, $1.75 next 50 feet, $2 next 50 feet, $2.50 next 50 feet, 6-inch pipe, 286 feet.

Somervell County.—Glen Rose: 75 cents per foot first 100 feet, adding 25 cents per foot for next 100 feet.

Stephens County.—Wayland: 50 cents per foot first 50 feet, 25 cents per foot additional for each 50 feet.

Tarrant County.—Fort Worth: 50 cents for the first 100 feet.

Taylor County.—Merkel: Well dug 10 by 10 feet, 70 feet, $8 per foot; boring, $1 per foot.

Uvalde County.—A flowing well 102 feet deep cost $125.

Webb County.—Cactus: $1 per foot first 100 feet; $2 per foot the next 70 feet.

Wise County.—Hoggsett: $1 per foot 6-inch well; $1.50 per foot 8-inch; $2 per foot 10-inch wells, 198 feet.

Dallam County.—Tascosa: About $1 per foot.

Glasscock County.—Garden City: Dug wells 4 or 5 feet diameter, 25 feet deep, $2 per foot.

Hockley County.—Six-inch bore, 200 feet, at $1.50 per foot.

Lubbock County.—Suiger's Store, 5 and 6 inch bores, $1 per foot for the first 100 feet and 50 cents rising with each 100 feet.

Potter County.—Amarilla: $1 for the first 100 feet and 50 cents per foot additional for each following 100 feet.

Val Verde County.—Del Rio: 6-inch bore $1.50, $2, $2.50, rising with each 100 feet 50 cents per foot, 300 feet.

El Paso County.—Torbert: $4 per foot first 500 feet: $6.50 per foot next 500 feet both 8-inch bore; third 500 feet $9 per foot, 5-inch diameter of bore.

Pecos County.—Dryden: General price $2 per foot without casing.

Reeves County.—Pecos City: $1.50 first 100 feet; $2 per foot second 100 feet. Same price for different bores.

LOCAL OPINIONS AS TO PRESENCE OR ABSENCE OF ARTESIAN WATERS.

[District No. 1, subhumid region.]

Archer County.—Salt water at 500 feet, but there are deep fresh-water wells in the county.

Atascosa County.—Nic Bluntzer, Pleasanton post office: "I think that a great many artesian wells could be made at from 500 to 1,000 feet deep in this and adjoining counties."

Bexar County.—Geo. W. Russ, president West End Town Company, San Antonio: "I am satisfied artesian water can be had in many portions of southwest Texas at small cost and will treble, at least, value of land."

This company has 2 wells, 260 feet deep, flowing 150 gallons per minute; cost $500.

Comanche County.—E. S. Atkinson, editor Comanche Chief: "I think an abundance of water could be obtained at a depth of only a few hundred feet."

T. R. Hill, Comanche, Tex.: "I believe water could be had to flow at 800 to 1,000 feet, judging from wells east and south of us."

Concho County.—Vigo, Tex.: Jno. T. Pruitt, postmaster: "There are thousands of acres of land lying around me that can not be surpassed in richness. If the artesian-well system was applied to these lands there is no figuring on the results. The writer is of the opinion that this system and none other would increase the amount of rainfall just in proportion to amount of water brought to the surface."

Coryell County.—J. M. Davidson, Pecan Grove: "Flowing wells are from 130 to 600 feet, and a beautiful showing for irrigating this farming land."

Erath County.—J. L. Humphries, county judge, Bluff Dale: "It is believed that artesian water can be had here most anywhere by going deep enough, from 1,000 to 2,000 feet."

Gillespie County.—A. W. Engle, Luckenbach post office: "There are no artesian wells in this county and I don't think there will be one."

Hill County.—J. O. Files, Files's post office: "I think that artesian water could be obtained anywhere in my vicinity by going deep enough, and, as a general rule, the deeper the stronger the flow."

Johnson County.—W. M. Crook, Cresson, Tex.: "No flowing well in this section. Artesian water is secured at from 150 to 300 feet."

McCulloch County.—J. L. Spiller, Vacca post office: "I think a tesian water could be had at about 1,000 feet. We have other wells here at 75 feet."

Taylor County.—J. L. Vaughan, Merkel, Tex.: "Think a flow can be secured between 500 and 800 feet."

Callahan County.—D. Richardson, Baird, Tex.: "If any test is made in Callahan County, some point immediately east of a sand flat, lying on the north of the railroad track opposite survey No. 79, B. B., B. and C. Railway survey should be used."

DISTRICT No. 2.—SEMI-ARID REGION.

Andrews County.—M. B. Cranston, of Midland County, and W. T. Stewart, of Dallas, well drillers, state that "a strong flow of artesian water of good quality can be expected at a depth of 200 feet."

They base their opinion upon the fact that in nearly every well bored in the county the water rose almost to the surface, and they express the belief that by boring a few feet further a flow could have been secured.

Dallam and Hansford Counties.—Aaron Canott, Farewell post office, Dallam County: Thinks flowing wells can be obtained in these counties, as they exist in Kansas, north, and in Texas, south and southeast. Says "sheet water is found at 100 feet (or less) to 200 feet, and if flowing wells could be secured immense crops would result."

Lipscomb County.—Eli C. Gray, Higgins, Tex.: "A belief that artesian water can be had at a depth of 500 to 1,000 feet here is based on the fact that our county is like Meade County, Kans., in surface, and that we lie in the same longitude."

Ochiltree County.—E. P. Klapp, Cresswell, Tex.: "The water does not rise any, either in dug or bored wells. There is no artesian well in this part of the country."

Fisher County.—W. C. Breedlove, Roby, Tex.: "I handed the blanks to an experienced well borer here. He looked over them and said there was no artesian water in this section of the country."

Hale County.—Horatio Graves, Epworth post office: "I have always supposed that artesian wells could be made to work here; that water could be found here at 1,000 or 2,000 feet. I would like to see one tried here."

Hall County.—Alex. Stine, Salisbury: "I am of the opinion that artesian wells can be got in this locality."

Southern Staked Plain.—It is the opinion of Mr. W. S. Marshall, of Fort Worth; W. V. Johnson, of Colorado; M. B. Cranson, of Midland; A. Rawlins, of Marienfeld; G. H. Stewart, of Midland, and W. T. Stewart, of Dallas; Mr. Robinson, of Garden City, all practical watermen, and also of a great number of ranchmen who are directly interested, that flowing wells can be obtained there at a depth of 500 to 1,500 feet. They limit their opinion to the Staked Plain, but have doubts as to whether water will be found between the Staked Plain and the Colorado River, or south of the plain toward the Rio Grande.

Scurry County.—A. C. Wilmeth, Snyder post office: "We have no artesian wells in this vicinity, though we thoroughly believe that we can secure one by boring 300 feet or more."

El Paso County.—Sierra Blanca, G. W. Hutchins: "Three wells bored here at 1,000 feet each; water must be raised 905 feet by steam power, too bad and too costly for purposes of irrigation." El Paso: It is believed that flowing water can be had, and an appropriation of $25,000 has been made by the city council to ascertain. A contract has been let, the parties to bore 2,500 feet if necessary

Jeff Davis County.—H. M. Patterson, Fort Davis: "We think artesian water can be gotten here."

Reeves County.—Dr. J. J. Inge, of Pecos City: "Our artesian belt is from 40 to 100 miles wide and extends from New Mexico line as far south as the Davis Mountains, about 150 miles. We have just finished 4 new flowing wells this week. We have in the county now 23 in all."

[State Geologist Report, 1888.]

Prof. W. von Steeniwitz, geologist for western Texas, speaking of the high lying plains between the mountains of El Paso, Jeff Davis, and Pecos Counties, says, p. 43: "The boring of artesian wells with an overflow to the surface has proved a failure in these prairies, as I predicted years ago that it would. The wells alongside of and in the hills will never supply a sufficient quantity of water for irrigation, to develop this part of Texas and make the land as valuable as it might be made at comparatively very moderate cost by reservoirs constructed by the combined efforts of the State and railway companies."

Gustav Jerney, geologist for the counties of Gillespie, Kerr, Kendall, Bexar, Blanco, Comal, Wilson, Guadalupe, Gonzales, and Caldwell, reports as follows:

Mineral waters and artesian wells.—Springs of mineral water are found in Kerr County, 2 miles west of Kerrville, and sulphur water at Sutherland Springs, in Wilson County. There are rich sulphur sprin s near the Cibolo, which are used by many visitors for bathing purposes.

The territory contains but few artesian wells, and these were sunk for the specific purpose of obtaining water. Among the most prominent of these wells I would mention the following: One of a depth of 225 feet in the western addition to the city of San Antonio, with a fine quality of drinking water, which forces its way to the surface. Another 4 miles east of San Antonio, near the Salado, which was sunk to a depth of 450 feet, and also brings a constant stream of water, containing hydro-sulphuric acid, to a considerable height. It is clear, and is being utilized for the ordinary wants of man and beast, but could be made more useful on account of its medical qualities.

Petroleum.—A more valuable well has been sunk about 7 miles south of San Antonio, which, instead of water, at a depth of 350 feet uncovered a deposit of gray clay ranging down to a depth of 420 feet, which is thoroughly impregnated with tar. This tar is of a sirupy consistence and of a dark yellow color. The well thus far gives only a barrel of 20 gallons of the tar per day, but nevertheless has been brought into market as a lubricator for wagons, etc. It contains a large quantity of coal oil, but is not refined. There seems to be no doubt whatever that this is the distilled product of a deeper and large bed of brown coal.

Prof. J. L. Pait, reporting on Atascosa County, says:

"In some of the wells unmistakable evidence of petroleum existing below is found. The smell is sometimes so strong in digging wells that they can not be proceeded with, and thin films of oil are found floating on the surface of others. No one in this county has bored for oil so far as I am aware, but I think a boring of a few hundred feet, where these signs are most apparent, might show some important results in that direction. As bearing on this point, Mr. George Dalling, when boring for water on his place at a depth of 300 feet, struck petroleum, and subsequently in another boring 270 feet, at some distance from the first, also came upon i . The flow affords about 20 gallons per day, but it is regular and continuous, and I think would indicate a natural reservoir of some volume."

Reporting on Frio County, he says:

"Near Cevilla Creek, on the property of T. J. Cavender, a strong brine made its appearance at 18 feet down on boring for water. It is a matter of remark in that section that almost every boring or digging for water discloses mineral waters, either sulphur, chalybeate, or alum, separate or in combination, and the same remark seems to apply to the waters of La Salle County, which especially to a stranger are noticeable and the reverse of agreeable."

Prof. J. Owen, reporting on Edwards, Maverick, Kinney, Uvalde, Val Verde, and other counties, says:

"The arid condition of this part of the State renders farming very unsatisfactory without an artificial supply of water; but while nature has withheld from us the needed rainfall, she has been lavish in her provisions for our necessities, and we only need the finger of science to point to her rich provisions for our needs and bring to light the hidden resources that are within our reach.

"A line drawn from a point on the Nueces River south of the town of Uvalde to a point 10 miles west of Carrizo Springs, thence south to the Rio Grande, will represent the outcrop of a *sand bed* nearly 200 feet thick. This sandstone has a monoclinal dip to the southeast. It is a very loose, coarse, friable sand, and free from any deleterious salts, and is an inexhaustible reservoir capable of furnishing water sufficient for irrigating purposes. This sand stratum supplies the numerous wells at Carrizo Springs,

and an example of its capacity may be seen at the ranch of Mr. Fayette Vivian, 10 miles north of Carrizo. This well is 175 feet deep and produces a stream of excellent water 4 inches in diameter. This sand lays conformably upon the rocks of late Cretaceous, and will be found at Laredo at a depth of about 500 feet. At this place all water obtained above this sand will be so strongly impregnated with mineral salts as to be unfit for use. This mineral water can be shut off, however, and the pure water from the Carrizo sandstone obtained. In the northwestern part of Zavala, the western part of Uvalde, and the northern parts of Maverick, Kinney, and Val Verde Counties we can never hope to obtain artesian water for agricultural purposes, but water may be obtained for domestic purposes by boring and pumping to the surface. These localities are so near the apex of an anticlinal ridge that we can never hope to obtain artesian water in them, and the only prospect of obtaining water for agricultural purposes in this locality is to bring it from the Rio Grande and the Devil Rivers.

"At the town of Uvalde I found a synclinal valley, resulting from an uplift by the trap dike and the volcanic cone west of the town. This synclinal basin has been partly filled by the débris of the drift period, and subsequently filled to a level with the surrounding country by the bluff formation, thus presenting to the eye a level plain. This provision of nature is of the utmost importance from the fact that this gravel deposit affords an immense reservoir for water, and wells sunk into this to a depth of 40 or 50 feet afford an inexhaustible supply. This water has to be pumped to the surface, and it is hardly probable that at this place artesian water could be obtained except at a very considerable depth."

As to artesian waters in Zavalla County, he says:

"An abundance of artesian water can be obtained by boring into the red sandstone series of rocks underlying the coal series about 150 feet. This sandstone will be from 90 to 150 feet thick in this county and will afford an abundance of excellent artesian water."

Dimmit County.—The west line of this county will pass near the western limit of the Carrizo sandstone. The top stratum of this sandstone has about 40 feet of red sand, which gives its characteristic color to the soil where it is exposed. The base of this series of rocks is composed of gray and brown sand, and some of the more indurate strata will answer for building stone. The courthouse at Carrizo is built of this stone, and it is the source from which the wells of Carrizo are supplied with water, and at any part of this county east of the outcrop of this stone there will be no difficulty in obtaining artesian water. This sandstone in this county is about 200 feet thick, and at the eastern line of the county it will be found at a considerable depth below the surface.

El Paso County: Fort Hancock.—Major Logan, in command at Fort Hancock, on being questioned by a reporter of the El Paso Tribune, stated in substance that in his opinion there is an immense body of water underground, in the valley of the Rio Grande, at El Paso.

"These mountain ranges can be followed away up into Colorado. If all the water that falls in the basin east of the mountains could be put into earth, it would not begin to make this immense body of water. It must come from the west of the mountains, from the Colorado Cañon and New Mexico. I believe it flows down here under bed rock and forms a vast reservoir and that the 400 feet of water (on Lanoria Mesa) is what percolates through crevices in the bed rock and forces its way in spite of the pressure of sand to within 200 feet of the surface. I believe that when a well is bored through bed rock a flowing well will be had. From all my observation I can not see any reason why we should not get plenty of water at a reasonable depth." A Government well was bored 275 feet at Fort Hancock, but discontinued on account of defective machinery. At one stage of the boring the water rose within 7 feet of the ground.

Runnels County.—J. R. Crayton, Content post office: Plenty of wells, 20 to 25 feet, and some springs. The mean annual rainfall is about 27 inches, and is usually so distributed as to insure winter and spring crops, but more or less protracted drought sometimes prevail in summer, though irrigation as a rule is not deemed indispensable to fairly successful farming. (State Report, 1882.)

Somervell County.—Dr. Scott Milam, Glen Rose post office, reports "We have some 200 artesian wells within 10 miles of town, all flowing. Some of the water white sulphur, some iron, but the greater number of them pure freestone water. They range in depth from 70 to 300 feet; flow daily from 2 to 200 gallons per minute, owing to depth. Not used for irrigation, except a little for gardens. The cost is generally 75 cents per foot for first 100 feet with 25 cents per foot added for each additional 100 feet." Water not analyzed, but used for domestic purposes, stock, etc., and with good effect wherever tried in gardens.

Somervell County.—George Abel and others, Glen Rose: About 200 flowing wells in the county, mostly used for domestic purposes, and for irrigating ribbon cane and

sometimes cotton. Mr. Abel's well, depth 260 feet, flow 40 gallons per minute, is thought by him to have sufficient water for 40 acres. Irrigation is considered necessary for a full development of the crop half the time. The effect of the water on vegetation is good.

Stephens County.—In the neighborhood of Wayland, or rather within a radius of 2 miles of Wayland, is a nest of flowing wells, some 8 or 10 probably, varying in depth from 100 to 180 feet and in cost from $50 to $200. The flow is given at 3 to 5 and 10 gallons per minute, varying with the different wells. The water is used for domestic purposes and irrigating in a small way. The irrigating capacity of these walls is estimated at from 10 to 25 acres, and irrigation is thought necessary in March and May. Deep borings for flowing water have been made in other parts of the county, but without success. Ordinary wells are usually obtained at a depth of 15 to 60 feet. The mean annual rainfall is about 27 inches, most abundant in fall, winter, and early spring, late summer crops being sometimes injured by drought. (Texas Report 1882.)

Shackelford County.—There are no artesian wells in the county. Common dug and bored wells, varying in depth from 30 to 50 feet, are very numerous and in all parts of the county. The water is generally very good, but is hard in a few wells. Some of the wells dried out during the drought of 1886, but the great majority furnished water abundantly. There are quite a number of small reservoirs or "tanks" for stock water in this and also in Stephens County. If the same method were also adopted fcr purposes of irrigation, the value of products of the farms could be increased considerably. The mean annual rainfall as registered at Fort Griffin is: 1878, 29.77 inches; 1879, 18.93; 1880, 28.71 inches; and for 1881, 20.86 inches, being most abundant in the months of May, June, July, September, October, and November in each of the years.

Tarrant County.—There have been bored in the city of Fort Worth alone over 242 wells, most of which did at one time flow from 5 to 50 gallons per minute. The depth ranges from 200 to 300 feet in the city, though one well now in course of construction is contracted for 2,500 feet or less, if a flow of 500,000 gallons per diem is secured. With the growth of the city the demand for water increased and steam-pumps applied, which extract 75 to 100 gallons per minute from wells that only flowed 10 gallons. The result is that all the artesian wells in the city except two have ceased flowing. In addition to the loss of pressure by pumping a large number were bored near the river bed, and these, though they helped rob the upper wells, have also ceased to flow. Mr. Wheeler, manager Artesian Ice Company, Fort Worth, gives the following history of the wells in Fort Worth:

"At present there are but two flowing wells in the town, as all the larger wells are being pumped. The first well in town was on the highest point, about 100 feet above low water in the river. This was a flowing well. Later on a considerable number were bored along the river bed, about 20 feet above low water. The result was that all the upper wells ceased flowing. The lower wells are also pumped now and only flow when there is no pumping. The average depth is about 300 feet and 242 are said to have been bored. On the south end of the town 120 feet above the river the depth is about 360 to 375 feet. The water apparently lies in a sheet, originally under great pressure, which by the numerous borings has been greatly reduced. Water in abundance can be had at any point in town by boring to this sheet or one underlying it."

The two railroad wells are pumped to the extent of 90,000 gallons in twenty-four hours. The one well has a depth of 450 feet and the other of between 700 and 800 feet, the deeper of the two furnishing a very small amount of water. In the county there are a considerable number of bored wells. The water rises in all of them, but only 10 or 15 are said to be flowing. Hardly any of the water is used for irrigation unless it be to water flower gardens or sprinkle lawns. Common wells are between 15 and 40 feet in depth. The rainfall is about 36 inches.

Taylor County.—An artesian well to be bored 2,500 feet is under contract at Abilene, and some $13,600 are to be paid for the work. Common wells vary in depth from 20 to 60 feet. Sometimes a boring of 15 to 25 feet is made below this and a largely increased supply obtained. Mr. J. L. Vaughan, of Merkel, Tex., gives the capacity of the railroad well at Merkel at 30,000 gallons per diem, which, according to his estimate, will irrigate 35 acres. The water could be raised by wind power or steam and stored in large tanks. The general altitude of the county is about 1,634 feet and the average rainfall 30½ inches, the heaviest rains falling in May, June, July, and August, and the lightest in April, October, and November. Small grain mature with reasonable certainty nearly every year, but fine fruits and vegetables need irrigation. Corn and small grain could be greatly benefited two years out of five. Small gardens and orchards are irrigated from common wells and windmills. The Cedar Springs well, about 1½ miles east of Abilene, is 5 feet in diameter and 40 feet deep. It yields 42 gallons per minute when pumped. In the vicinity of Merkel water in abundance

is found at a depth of 16 to 20 feet. All the wells between Merkel and Anson, in Jones County, are of the same depth and have freestone water. None of them are known to fail. Most people use windmills. A few irrigate, and 5 acres is considered the limit of an ordinary well. By using storage reservoirs the capacity can be increased to 15 to 20 acres per well. In the west half of Taylor, all of Jones and Haskell Counties water is said to be abundant at 15 to 25 feet, and in the vicinity of Buffalo Gap, about the center of Taylor County, the average depth is 15 to 16 feet.

Another primitive method of irrigation is in use within 2 miles of Abilene. Two industrious Chinamen operate a 6-acre garden, and produce the finest vegetables grown in the country. The garden is situated between two streams that form a junction near town. Two sweeps about 16 or 18 feet long are securely fastened to a pair of mesquite trees in such manner as to swing freely. On the end of each sweep is a 5-gallon coal-oil can, which is lowered into the creek, then raised and emptied into a ditch and then carried to square holes in the garden distributed at intervals of 30 feet. Close to the holes are small beds divided by furrows, and when the crop needs water it is raised by hand in small buckets, and put where it will do the most good. On being questioned as to why they did not use a windmill, the Chinamen replied that it was too expensive a commodity to have on so small a garden.

Throckmorton County.—The mean annual rainfall is 24.90 inches, and the seasons are irregular, being usually more propitious for small grain than for corn and other crops maturing in summer. Wells of good water can be obtained easily at almost any desired point in the county. (Texas Report, 1882.) Common wells 12 to 50 feet in depth.

Uvalde County.—Two artesian wells in the county, at Utopia, on the same ranch, about 200 feet deep. Wells for stock are obtained at a moderate depth. The mean annual rainfall was, for 1878, 23.97 inches; 1870, 19.22 inches; 1880, 31.29 inches, and for 1881, 21.54 inches; the highest monthly mean being in May and August. Irrigation is necessary to insure uniformly fair crops, facilities for which are moderately convenient by means of ditches from the mountain streams.

Webb County.—Mean annual rainfall, 1877, 21.39; 1878, 27.49; 1879, 21.51; 1880, 26.73; 1881, 26.67 inches, the greatest precipitation being in February, May, and August of each year. The rainfall is irregular; irrigation is required for successful farming, and can be obtained at many points on the Rio Grande at moderate cost. (State Report, 1882.) Several flowing wells have been secured in this county, but the flow was very weak, and the water obtained not suitable for purposes of irrigation.

Wilbarger County.—C. F. Doans, Doan's post office: "There is no artesian well in Wilbarger County. The rainfall from April 1 to September 1 is generally sufficient for wheat and oats, and in fact for most all small grain, but the corn crop is very uncertain. There are large fine springs around Doan's, but none of the water is used for irrigating purposes."

The mean annual rainfall as registered at Fort Griffin, 75 miles south, is 24.57 inches. In this county the heaviest rainfall is usually in April, May, and June, and late summer crops are sometimes cut short by drought, but there is usually ample rainfall in winter and spring to insure an abundant yield of the cereals and other crops maturing in the spring. Much of the water in the streams is impregnated, to a greater or less extent, with salt, gypsum, or lime, and is not palatable; but for domestic use water is obtained from springs which are numerous and from wells, obtained in most parts of the county at an average depth of 20 feet. (State Report, 1882.)

Young County.—Carbondale. Water found in borings of 80 to 150 feet always contains more or less salt. Ordinary wells throughout the county vary in depth from 20 to 100 feet. The mean annual rainfall, as registered at Jacksboro is 26.20 inches, and is most abundant in May, June, and July of each year.

Somervell County.—E. R. Bull, Paluxy, Hood County: "Three flowing wells I bored are 285, 275, and 259 feet deep, no casing used, cost $11 per foot. Diameter of bore 6 inches, and flow about 300 gallons per minute; some wells have failed and none have gained in flow. The flow generally has diminished. Water used for all purposes and is very good for irrigation, and pays well for everything irrigated. Most of the wells are so situated that the water can be stored, and the wells were estimated to irrigate from 10 to 50 acres each. Irrigation is beneficial perhaps one year out of three. I never kept an account of all the strata or their thickness. The wells flowed at about 100 feet and increased slowly until the last 5 or 6 feet, when the flow increased very rapidly, making about a 5-inch flow. There are perhaps 75 or 100 flowing artesian wells in Somervell County; they vary in size of flow and bore. Some flow very strong, others very weak where they are plenty. They sap each other; the one on the highest ground suffers worst. Sometimes those in the highest places dry out altogether."

DISTRICT NO. 2, SEMI-ARID REGION.

This section of the State will for years to come be more extensively used for raising stock than for general farming operations. In localities where water is abundant and can be cheaply obtained small farms will be cultivated under irrigation; but the water required will in most cases have to come from below the land to be irrigated. In a very large area there is water in abundance at a shallow depth; in other localities it will have to be stored. There are not exceeding four flowing wells in the district, and these were found accidentally. There is not sufficient evidence in the way of deep borings to prove either the existence or non-existence of great bodies of artesian water, but if it can be proven that they do exist, crop making will be reduced to a profitable business in a very short space of time. Most farms there now under irrigation are generally operated in connection with either a cattle or sheep ranch.

Borden County.—Water is generally difficult to obtain in wells of moderate depth. Where water is found it is good and abundant. Can learn only of eight or nine wells, and these are from 50 to 150 feet deep. One well 300 feet deep and no water. Failures to secure water are very numerous. No water can be obtained at a depth of 350 feet in the red-joint clay, and this seems to underlie the greater part of the county. There are not many good locations for storage reservoirs. Water when obtained is generally in wells 20 to 30 feet deep, accumulated in depressions in this clay bed, and held there in suspense.

Cottle County.—A large number of common wells have been bored in this county with an average diameter of 6 inches and an average depth of 100 feet. The water in nearly all the wells is impregnated with gypsum or salt. The large springs in the county also carry salt or gypsum. My informant, Mr. Dumont, of Otta, Tex., is of the opinion that none of this water could be used for irrigation purposes.

King County.—A copper mining company bored 1,500 feet in this county, but secured no flowing water.

Hardeman County.—The same company also bored a 1,500-foot well in this county and failed to get a flow.

Cottle County.—There is an underground stream in this county that might possibly be turned to account for irrigating purposes. Gypsum water does not seem to hurt vegetation, and is used for this purpose in other places.

Crosby County.—H. C. Smith, Mt. Blanco post office: "There are several wells in the Kentucky Cattle Raising Company's pasture that would come to the surface and flow good streams of water if properly cased off. The water of four or five large springs, I am satisfied, would rise to the surface of the plain 250 to 300 feet, if it was confined."

In the northern part of the county water is obtained at 70 to 90 feet. On the cap rock of the plains (staked), or rather the edge of same, from 200 to 300 feet. There are about 150 to 200 wells in the county. Agriculture, with more or less success, has been carried on in the county since 1879. In the southwest corner of the county is Yellow House Creek, a large running stream, and Spring Creek, and in the southwest part of the county is a bold running stream of 3 or 4 miles length, each of which is deemed capable of irrigating from 500 to 1,000 acres. Those creeks are 200 to 300 feet below the general level of the staked plain, but there is said to be plenty of good land convenient to them. There are many localities in the county where large quantities of storm water could be stored and made available during the dry months.

Crockett County.—There are 25 bored wells in the county, almost all of them on the "draws" or ancient river beds. The first well bored in the county is 7 miles south of the center of the county and 392 feet deep. There is a bored well on survey 3, block I. J., 158 feet deep; one on block E. F., 245 feet deep; one on survey 22, block 2, 224 feet;

one on survey 1, block F. 2, 260 feet; one on survey 7, block O. P., 225; one each on surveys 20 and 48, block O. P., 225 feet deep; and one each on surveys 66 and 49, block G. H., 250 feet. This county is south of the Staked Plain, and it appears that the farther the distance south from the plain the deeper the wells. There are two underground rivers in the county described elsewhere. The soils in many parts of the county are clayey, and if used for storage reservoirs would hold water well.

Dallam County.—A. Canott, Farwell post office: "The rainfall is varying. This is an undulating prairie country, but a little too dry. There are flowing wells north and south of us in Kansas and Texas, and I believe they can be secured here, but no effort has yet been made, as the country is mostly taken up by cattle men, who depend upon the streams. Plenty of sheet water is found at a depth of 100 feet (or less) to 200 feet. Number of springs along the streams. The soil is fertile, and with flowing wells to insure irrigation it would be one of the most productive parts of the S uthwest."

Dawson County.—There are probably not exceeding fifty wells in the county, all bored and varying in depth from 50 to 100 feet.

There is considerable difference in the stratification passed through, but greater certainty of finding it here than in Borden County. It is generally found in sand. The average cost of boring and furnishing all appliances necessary to raise water is from $4 to $5 fer foot in depth. In Sulphur Draw, running through Dawson and Terry Counties, are eight or ten bored wells about 60 feet deep in sandstone that afford a most excellent supply of fresh water.

On the cattle ranch of Mr. C. C. Slaughter are ten large reservoirs. The largest is on Rattlesnake Draw, running into Colorado River. The dam is about 1,000 feet long and backs up the water, which is 25 feet deep at the dam, 1½ miles. This reservoir is fed by springs extending for miles along the draw above it. The construction cf the reservoir has given birth to numerous springs below. The drainage area of the reservoir is very large and the water supply is permanent. The cost of the dam was $1,700. Several other equally large reservoirs could be constructed on this draw without injury to the one mentioned.

Oldham County.—J. C. Hatchell, Amarillo, Potter County: "The Lee Scott Cattle Company have a flowing well 230 feet deep, but 600 feet below the level of the plains. It flows 15 gallons per minute." The supply of this well is probably purely local, being situated, as it is, in a depression or cañon of the Staked Plain. The general altitude of Olham County is 3,600 feet. The deepest well in the vicinity of Tascosa is 240 feet deep, and many are less than 200 feet in depth. The water in all of them is soft and inexhaustable to windmills, which are extensively used and kept in motion continuously.

The water in all of these wells rises from 30 to 80 feet, increasing in pressure as depth is gained. The diameter of bore is generally 6 inches, and most wells are cased. The cost of drilling is from 75 cents to $1.25 per foot. A considerable number of common wells for domestic use are from 15 to 40 feet deep. There has been no record of the rainfall by judging by other counties. It might be safe to estimate it at 17 to 25 inches, more or less irregular in precipitation. Irrigation to secure perfect crops would be necessary, say one year out of three. It is thought that flowing water could be secured on the open plain at a depth of 1,500 feet.

Donley, Armstrong, Crosby, Swisher, and Oldham Counties.—Annual rainfall about June, July, and August, and late in autumn. Water in common wells is easily obtained in Donley County. The wells in the other counties range from 40 to 300 feet in depth, and cost an average of 60 cents per foot. All are operated by windmills using 3-inch cylinders. On the Goodnight ranches, situate in these counties, are forty-seven reservoirs from 1 acre to 5 acres in extent, varying in depth from 3 to 10 feet. The average cost of construction is about 9 cents per cubic yard of dam, and from 3,000 to 10,000 cubic yards are used in the construction of a reservoir. Agriculture consists in growing sorghum or other forage.

Andrews County.—This county is wholly occupied by cattle ranches, at whose instance about sixty to seventy wells were bored, ranging in depth from 47 to 90 feet. The water in all these wells is strongly artesian, and in nearly every well comes within 1 to 20 feet of the surface. Well-borers who have worked in this county express it as their opinion that flowing wells could be had anywhere in this county at a depth of 200 to 300 feet.

Ector County.—The Odessa Improvement and Irrigation Company made one attempt to secure flowing water and bored 832 feet, passing through nearly 700 feet of red joint clay. Owing to a mishap to the casing, making further work impossible, the boring was discontinued. As the experiment was a new one and the machinery employed inadequate no further attempt was made as to bored wells, but one was dug for irrigating purposes, of which the following is a description:

Shaft: 8 x 8 feet square, curbed 21 feet from the surface. From curb to surface of water, circular form, 15 feet 6 inches. Diameter at bottom of curb, 8 feet; at water line, 12 feet. Reservoir, 12 feet in diameter at water line and 16 feet at bottom of

well. Depth of water, 11 feet 6 inches. Depth of well, 48 feet. Reservoir capacity of well, 14,500 gallons. Materials passed through: Soil 7 feet; rotten limestone, 14 feet; concrete rock, 16 feet—very hard and difficult to work; soft sandstone and gravel, 11 feet; water found in gravel. Amount of water furnished by well, 5,000 gallons per hour, perpetual pumping. Test made with Knowl's stem pump: Capacity, 6,000 gallons per hour. Cost of well, $568.03.

With steam pump working ten hours per day, this well will yield 50,000 gallons of water daily, or sufficient to cover 2 acres of land with water 1 inch deep. Worked five days per week, during the year, it will give 2 inches of water per month to 20 acres of land, or the equivalent of 24 inches annual rainfall, or 12 inches per annum to 40 acres. The latter amount with the rainfall is simply sufficient for orchard and vineyard purposes at this point.

A 20-foot windmill is employed in raising this water, which is stored in a reservoir built above ground, so that it lies higher than the farm. It is 75 feet square and 5 feet deep and holds about 210,000 gallons. It is built of the sandy loam of the county and is lined with a coating of tar on the inside, which makes it perfectly water proof. The walls of the reservoir are 6 feet high, 4 feet broad on the crown and 13 feet at the base, built like a railroad fill. The windmill exclusive of tower and pumps, cost $250, and the reservoir complete cost $250. The company irrigate 20 acres of fine California grapes and fancy fruits and can serve double the acreage with their present water supply.

Rev. C. Golder irrigates an orchard of 5 acres from a well 56 feet deep, 4 feet diameter at the mouth, and 7 feet diameter at the bottom, holding 6 feet of water. The well is pumped by a 12-foot windmill, and is deemed ample and sufficient for 20 acres in grapes or fruit. Mr. W. White's orchard and vineyard is distant one-half mile from Odessa Station. It is irrigated from a dug well 60 feet deep, with a boring of 60 feet more in the bottom. The water is pumped by a 14-foot windmill, U. S. make. The supply from this well is deemed sufficient for 30 acres of orchard and garden. Connected with the well is a circular irrigation reservoir, 60 feet in diameter, 8 feet deep, holding about 169,560 gallons. The wall of the reservoir is made by scraping out the soil of the interior, being 6 feet high on the outside and 9 feet on the inside. Three feet of the reservoir are below the level of the field, and is used as a fish pond, the irrigation water being drawn from above this point. The reservoir is lined with tar and pitch, and is made water proof. The cost is figured as follows:

500 cubic yards of dirt, at 15 cents	$75.00
5 barrels of tar, at $15	75.00
Labor, etc	25.00
	175.00

The 14-foot windmill pumps about 20 gallons per minute in a strong wind, or about 11,000 to 12,000 gallons per day on the average. At the present time there are from fifty to sixty wells in Ector County, and about ten to twelve reservoirs. These are mainly used for watering live stock, are usually built of clay, have no tar lining, are water proof, and inexpensive. The average cost of a well in Ector County is $2 per foot for dug wells and $1.25 per foot for bored wells.

The Odessa Draw, an old river bed retired from business, affords an abundance of water at 6 to 10 feet, and below its rock bottom a river is said to flow. This underflow can be raised to the surface by syphon, as explained elsewhere in this report.

Upton County.—In this county there are from thirty to forty wells, varying in depth from 30 to 100 feet. They are all used for watering live stock.

Floyd County.—About one hundred and twenty-five wells, 25 to 30 feet deep, with excellent water in abundance, all raised by 10 and 12 foot windmills. Most ranches have small farms attached to them, which are irrigated from these wells. Between May and August there are hundreds of depressions or lakes that are bank full. Many of them are so situated that their water could be syphoned to lower-lying tracts and used for irrigation.

Hall County.—Has an underground stream described elsewhere. There are about one hundred and twenty-five wells in the county from 25 to 30 feet deep, costing complete, with windmills and pumps, $110 to $150. The irrigating capacity of these wells is estimated at 10 to 15 acres each, and a number of gardens are irrigated with them. They afford all the water demanded by 10 or 12 foot windmills, and none of them have given out in time of drought. The deepest well in the county is only 50 feet down. In common with Floyd County, there are here hundreds of small lakes holding water between, say, May and September, that could be made an important factor in irrigation.

Stonewall County.—Very thinly settled; are very few wells in the county, and some of these contain gypsum in the water.

Glasscock County.—Water abundant along Lacy Draw at an average depth of 20 feet about 8 miles east of Garden City. West of this place, in Mustang Draw, water

from 15 to 20 feet. This can be syphoned to higher lying lands. The depth in other parts of the county varies from 150 to 300 feet. In some localities red joint clay is encountered, and then the boring is at once discontinued. About 12 miles southeast of Garden City are the first waters of the North Concho suddenly rising out of the ground in powerful springs. On the Barnett & McIntyre ranch are nineteen or twenty wells, varying in depth from 60 to 90 feet. The water rises in all of them.

Scurry County.—A considerable number of dug and bored wells, say one hundred and fifty to two hundred, vary in depth from 50 to 80 feet, with a few that are shallower. Water is generally abundant and of fair quality.

Fisher County.—No deep artesian wells in the county. There are between two hundred and fifty and three hundred bored wells. The deepest boring was 265 feet and no water was obtained. The shallowest wells, and a considerable number are on the streams, vary from 4 to 25 feet. On the uplands away from the streams the shallowest are about 40 feet deep, the average 40 to 60 feet, and many 70 to 80 feet deep. While some wells have almost pure water a large number are more or less impregnated with gypsum. Cost of boring wells, 85 cents to $1 per foot. For drinking water, cisterns are largely employed. No land is at present under irrigation, and during the past three years fine crops have been grown without it.

Donley County.—James H. Parks, Clarendon: "We have numerous bored wells in this and adjoining counties that find water at from 50 to 250 feet. In some of these the water has risen 40 to 80 feet. The deeper the well the higher the water usually rises."

Fisher County.—W. C. Breedlove, Roby, Tex.: "All of the wells bored here go from 60 to 150 feet and afford an abundance of stock water. There has been a well dug on the square in this town 300 feet deep and no indication of water. In fact it is a dry hole."

Fisher County.—C. W. Morris, Hitson post office: "In this part of the country the majority of wells are shallow, ranging from 12 to 35 feet deep."

Glasscock County.—D. N. Morrison, Garden City: "J. I. McDowell well is 15 miles southwest of Big Springs, and 25 feet deep; cost $150, and is 4 feet in diameter; situate in Mustang Draw, and affords an unlimited supply of water; used for watering live stock and irrigating 5 to 8 acres in garden and orchard. Irrigation is necessary one-half or one-third the time."

Hale County.—Horatio Graves, Epworth post-office: "I have known this country since 1877 and have lived at Epworth since April, 1883; was the first settler in this county, and have raised good crops here. The last two years have been very dry and crops have been almost a failure. I have always supposed that artesian wells could be made to work well here, that water could be found at 1,000 or 2,000 feet. I would like to see one tried, and will give any information I have to facilitate the trying of a well in this, one of the best, if not the very best county, in northwestern Texas."

Hall County.—Alex. Stine, Salisbury post office: "Water in dug wells has been found at a depth from 2 to 120 feet, some soft, some hard, and some bitter. There is a belt of subirrigated land along the banks of Red River, and the same in the southwest corner of the county. I am of the opinion that artesian wells can be got in this locality. Springs are abundant along the heads of the creeks and breaks. Dams and tanks can be made at little cost for stock purposes. The expense for irrigating purposes would naturally be regulated by the location, etc."

Hansford County.—James F. Cator, Zulu post office: "Wells known to me are the following: A. L. Burgett's, Zulu, Tex., on section 14, block P, Houston and Great Northern Railroad Company, 160 feet deep, sufficient water for domestic uses; W. L. Ballard's, section 44, block P, Houston and Great Northern Railroad, 180 feet deep; Robert Rosenthal, section 46, block P, Houston and Great Northern Railroad, 146 feet deep; Farwell town site, 150 feet. These are not artesian wells, but they afford plenty of water for domestic purposes."

Ralph Bigger, Hansford post office: "The volume of water sufficient for stock and domestic use obtainable at from 25 to 180 feet on section 136, block 45, Houston and Texas Central Railway. An attempt was made to reach artesian water, but the machine failing to work satisfactorily, the well had to be abandoned at a depth of 130 feet with about 70 feet of water."

Aaron Carnott, Farwell, Tex., post office: "This is a beautiful plains prairie country, watered by the Beaver, Coldwater, Paladuro, and Canadian streams, with frequent springs. On the flats or level prairie water is obtained by digging or boring at from 100 to 150 feet, and plenty of water is secured. I don't think there is any doubt but that artesian water can be obtained here, when it is a success north of us in Kansas and south and southeast of here in Texas."

Hemphill County.—George Ford, jr., Canadian post office: "There is not an artesian well in the county. Water is obtained in wells at a depth of 40 feet to 110, average depth 100 feet. Where crops can be irrigated the yield has been large. Have not been down by boring or digging more than 150 feet.

Lynn, Terry, Hockley, etc.—There are a number of ponds with permanent waters,

some fresh, others salty or brackish, in the lower Panhandle. The most noted among them are Cedar Lake, 25 miles southwest from Tahoka Lake, in Lynn County, is a body of fresh water lasting all the year round and is fed by springs. It has an island of 7 acres in the center. Rich Lake is 18 miles northwest from Double Lake. Ranger Lake is on the line of New Mexico. Yellow House Lake, wells, and springs are 35 miles from Yellow House Cañon. Tahoka Lake is 70 miles north of Big Spring, in Howard County. Silver Lake is 7 miles west of Yellow House and 142 miles from Big Spring. Double Lake is 8 miles from Tahoka Lake. Four Lakes are 18 west from Ranger Lake. The Blue Holes are east of the Yellow House Lake, and Eagle Lake is southwest from Running Water, in Hale County. Each and every one of these lakes have good springs on the west side, but none are known to have such on the east side. The above description is as I got it from an old ranger. It would have required 6 months' surveying to locate them properly.

Lynn County.—In the north half of the county the wells are from 70 to 90 feet deep; in the southeast part of the county from 100 to 175 feet, and in the southwest part are only two wells, 190 and 200 feet deep, with very little water. There are two salt lakes and a considerable number of fresh water lakes in the county.

Howard County.—Most of the rains fall between April and September, the greatest quantity coming down in one or two rains. The annual rainfall varies between 15 and 24 inches, and irrigation for some kinds of crops is necessary every year. Forage plants do well without irrigation, and the same can be said of several fruit orchards; but it is admitted that they could be vastly improved by irrigation.

The town of Big Spring is situated in an ancient river bed, which traverses the county from east to west and can be traced northwest for nearly 280 miles. About 10 miles west of the town are several large salt lakes and soda springs, which empty into this old river bed, which is known as Sulphur Draw. In the vicinity of Big Spring are a number of dug wells averaging in depth about 25 feet. The water found varies greatly in quality. In the town the water is very salty, changing in the different wells to brackish, gypsum and fresh water; all the wells afford an abundant supply, but that of the salt wells is considered useless for any purpose. A few of the others are used for irrigation of tracts 1 or 2 acres in extent.

Away from town numerous borings for water have been made, many of them in the "draws." In these the depth is usually from 6 to 25 feet. Salt water is often encountered, but as a rule the water is good. There are, after April in each year, a number of small ponds that carry water for several months, but generally they dry out before the end of June. In the north half of the county red joint clay is often met with in the borings, and in several localities this has been penetrated to a depth of 400 feet without obtaining water. A similar bed exists some 8 or 9 miles south of the center of the county. The soils of the county are well suited to the growth of fine fruits, and there are several fine orchards and vineyards that have made a good growth and have fruited without the benefits of irrigation. Grazing is the principal source of income, and lands at present figures are worth from $2 to $3 per acre.

The wells outside of town are the following:

Roper & Evarts, three wells; dug 18 to 20 feet; good water.
Mr. Walcott, one well; dug 30 feet; good water.
J. Smith, one well; bored 150 feet; good water.
George Bauer, one well; bored 150 feet; salt water.
Devil's Elbow Ranch, one well; dug 30 feet; good water.
Mr. North, one well; dug 40 feet; good water.
On hill north of town, in joint clay; 90 feet; salt water.
Demarest Bros., 14 miles north; dug 30 feet; good water.
Ole Anderson place, 14 miles north; dug 60 feet; good water.
Morita Station; dug 25 feet; brackish water.
Ole Anderson's place, 2 wells; bored 125 feet; good water.
On sand hill east of town; 30 to 60 feet; good water.
Arkansaw Ranch; 100 to 130 feet; good water.
Well at Railroad shops; 300 feet; salt water.
County artesian well in town; salt water.

While the water supply in wells is variable as to depth and quality, there is no question but that immense quantities of water could be stored in this county and be used for irrigation. The county is sufficiently hilly to afford a considerable number of fine locations for storage dams, and the rainfall between April and October is sufficient to fill them in any year.

The overflow of Big Spring (described in another part of this report) is carried through a ravine or cañon, which three-fourths of a mile below could be stored by a dam 1,000 or 1,200 feet long and 40 feet high. The basin thus formed would be three-fourths mile long, one-fourth mile wide and 30 feet deep, and would hold about 275,000,000 gallons of good water. By building a larger dam lower down the quantity stored could be greatly increased. At one-fourth mile above the spring the ravine could also be dammed. This would raise the bottom of the reservoir about

40 feet and cover 200 to 400 acres. It would receive the drainage of about 20 square miles, and the bottom of the reservoir would be nearly 200 feet above the town of Big Spring and a very large acreage of fine agricultural lands. About one-half mile east of the Big Spring is another draw or ravine (unnamed), which drains 7 or 8 square miles. This could be made to hold a large amount of water and would probably irrigate 5 or 6 sections of land. On Morgan's Creek, in the northeast corner of the county, on section 3, block 30, township north, is a site for a reservoir that would hold the drainage of 40 to 50 square miles, and has below it a magnificent body of farming lands. A cheap dam could be made to irrigate from 10 to 15 sections of land. There are a considerable number of such locations in the county, all of which could be utilized for purposes of irrigation.

Irion County.—Seven hundred acres here at Sherwood under irrigation, watered from Spring Creek. J. M. Carson, county judge.

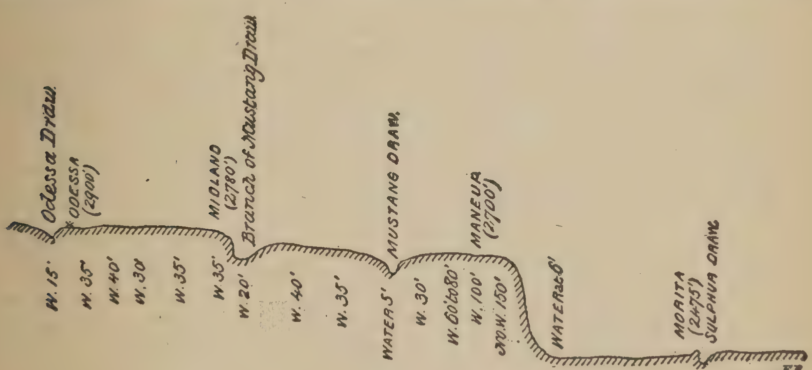
Kent County.—G. C. Harrison, Jayton post office. "The farming interest would be greatly benefited by means of irrigation, as this country is subject to droughts."

Lipscomb County.—John Wanger, Timms City. "Geo. R. Timms's well drilled 227 feet deep, and has 127 feet of water, which was struck at a depth of 150 feet. Elevation, 2,600. E. C. Gray, Higgins, Tex." There is no artesian well in this part, but it is believed that artesian water can be had at a depth of 500 to 1,000 feet. In Meade County, Kans., in the same longitude, artesian water is easily procured. Our county is much the same as Meade county, Kans., in surface and appearance. Rainfall about 20 inches, between April and September. Irrigation will be necessary every year in June, July, and August.

Lubbock County.—H. A. Goodwin, Snyder, Tex. "Dave Taylor, at Singer's Store, has a flowing well of shallow depth at White Lake, on the plains, flowing a 2-inch stream. The annual rainfall is about 15 inches, of which about 8 inches fall between April and September. Irrigation is necessary about one-fourth of the time."

Ordinary wells in the two draws of the Yellow House Lake, traversing this county, are from 6 to 15 feet deep. On the upland the depth is from 70 to 90 feet. The quality of the water is excellent and all wells afford an excellent supply. About 25 to 30 windmills are used in the county. The head of Yellow House Creek is formed near the center of the county by two branch draws, and into these flow a considerable number of springs.

Martin County.—Common wells on the uplands vary from 35 to 145 feet in depth. This county is situated on the eastern edge of the Staked Plain, and here, as elsewhere, the rule applies, that the nearer the well is to the edge the deeper will be the water line.



Common dug and bored wells are used in a small way for purposes of irrigation, and the experiments so far carried on have proved very profitable and successful. The Mareinfeld Fruit-growing, Gardening, and Irrigation Company have 20 acres planted in fruit trees and vines. They use two 8-inch bored wells, each 146 feet deep, and carrying 60 feet of water. They have one 20-foot United States mill and one 20-foot Perkin's mill, each capable of pumping 2,000 gallons per hour. A storage reservoir to cover an area 70 feet by 200, 6 feet deep, is now under contract. These waterworks are deemed sufficient for 60 to 80 acres in fruit trees and vines. The wells cost $682. The windmill towers and labor $757, and the storage reservoir completed with tar lining will cost about $300.

L. P. Glasscock's farm, orchard, and vineyard are situate on sec. 40, block 36, township 1, south. His well is 3 by 3 feet square and 20 feet deep, and is in Mustang Draw. This well furnishes 15,000 gallons per day, and in addition to irrigating 20 acres of land, is also used to water 2,000 head of cattle. He uses a 12-foot United States mill

and a 5½-inch cylinder. Two clay storage reservoirs, or "tanks," one of 135,000 gallon's capacity and the other of 269,000 gallons' capacity, are kept bank full all the time. The plant cost about as follows:

Well 20 feet deep	$30
Windmill, tower, and pump	75
Storage reservoirs	40
Total (about)	145

About 5 miles west of Marienfeld, on the Texas and Pacific Railway, is an irrigated orchard and vineyard belonging to Mr. A. Rawlins. He has 20 acres in cultivation. Good water in apparently unlimited quantity is obtained in 3-inch bored wells and carried by a 10-foot windmill to an irrigation reservoir lined with tar and built on the surface of the ground at an expense of about $50. The reservoir is 30 feet diameter, circular, and about 4 feet deep, holds about 22,000 gallons. The whole irrigation plant is worth about as follows:

Two wells, 30 feet, at 50 cents per foot	$30
One 10-foot mill and fixings	50
Storage reservoir	30
Total	110

As mentioned, in another part of this report there are several draws which apparently carry an unlimited supply of good water under the stone bottom of their beds. This water is struck at 5 to 15 feet. If a number of syphons were inserted into the bed of this draw (Mustang) and several others, it seems that water enough for several thousand acres could be obtained at a nominal cost.

Midland County.—Altitude, 2,780. One artesian well is reported from this county as flowing 500 gallons per minute. As a matter of fact, it is simply a shallow well which has penetrated an underground stream flowing under pressure. Irrigation in the county is considered necessary three years out of five. There are perhaps a dozen small irrigated orchards and vineyards in the vicinity of the town of Midland, and quite a number of gardens connected with ranches in the county.

Z. T. Brown's ranch has an orchard and vineyard about 7 miles south of Midland. There are about 20 acres planted in choice fruits. Altitude, 2,685 feet. The orchard is only a very sandy tract of land with a clay subsoil which retains all the water that falls on it, some 20 to 28 inches. He has a well 18 feet deep and uses a 12-foot Star mill, but has had no occasion to use any of the water for irrigating, as the soil provides all the moisture needed. The fruit trees and vines show a most vigorous growth and were well laden with fruit when I saw them.

Mr. J. S. Curtis's ranch is 6 miles north of Midland. Altitude, 2,800 feet. He has 4 acres in the European raisin and table grapes, all laden with fruit. He uses a dug well 30 feet deep, with 3 feet of water, which neither rises nor falls. The strata penetrated were 4 feet of top soil, then limestone, and then water in coarse white gravel. He uses a 12 foot Haliday mill, with double cylinders, pumping 8,600 gallons during 6 hours of each day, when there is wind. This water is pumped into a wooden storage tank, 16 by 18 by 4 feet, filled daily and used for a large herd of cattle as well as for irrigation. The entire cost of well, reservoir, and windmills is $300. This irrigation plant would serve 12 to 18 acres.

J. M. Moody's orchard, vineyard, and nursery comprises about 6 acres in the town of Midland. They are irrigated from a well 35 feet deep, costing $4 per foot. Ten feet of water standing permanently in the well. A 10-foot Haliday windmill raises 800 gallons per hour; twenty-four hours' continuous pumping does not seem to affect the well in the least. Irrigation is deemed most necessary in March and April of each year. In June, July, and August there are usually heavy rains. An irrigation plant like Mr. Moody's will cost about $300. According to his estimate dry lands that can now be bought for $2 or $3 per acre would be worth $500 per acre if made irrigable, at least his tract is not for sale at that figure.

N. S. Worley's orchard and vineyard consists of 10 acres in fruit trees and vines and is one-half mile from the town of Midland. He has one well 55 feet deep that carries permanently 10 feet of water and furnishes every eight hours 9,600 gallons. A second well now in construction, is 7 feet 8 inches in diameter at the mouth and 15 by 15 feet at the bottom. The water rises 7 feet above the bottom. A 12-foot Kirkwood windmill extracts all the water in twelve hours, both of these wells are 55 feet deep but the second well is being carried down to the next sheet of water below. The cost of the first well is $300, of the second $325. This includes the windmills and pumps for each. The water from both wells is pumped into a clay storage reservoir 60 feet in diameter and 6 feet deep, holding about 127,000 gallons, which supply is deemed ample and more than sufficient for 10 acres. The cost of this reservoir is $150.

Prices generally paid for borings are $1.25 for the first 100 feet, $1.75 for the second

100 feet, and rising at the rate of 50 cents for each successive 100 feet. The average cost of a well is $60, and the average cost of a windmill is $75. The average estimated capacity of an ordinary well and windmill for irrigation is from 3 to 5 acres the first year, double that acreage the second year, and possibly a large increase of capacity thereafter. By the use of storage tanks or reservoirs the acreage can be extended to 10 acres, and doubled the second year. Dry land is worth $3 per acre. When supplied with an irrigation plant worth $300 for 10 acres, it is valued at $50 per acre. Price recently offered for a 2½-acre tract fenced and planted with one-year old fruit trees, but without irrigation water, was $680, which was rejected.

Mitchell County.—There are about 75 to 100 wells outside of Colorado City, most of which are bored. In the northeast part of the county the wells are 80 to 125 feet deep, the water good and abundant. In the southeast part the depth is about the same and the quality good. In the northwest quarter of the county the depth on the upland is from 80 to 125 feet. In the Satan Valley and neighborhood of Morgan Creek good water is found at a depth of 10 to 25 feet. On the west end of Satan Valley the railroad made one boring of 70 feet and struck salt water. In the southwest quarter of the county the ordinary depth is 100 to 125 feet. Some of the wells in the northwest part of the county are a little alkaline. Windmills are extensively used. Corn, wheat, cotton, and oats are grown without irrigation. Vegetable and flower gardens are sometimes irrigated. The annual rainfall varies between 18 and 24 inches, most of it falling between the 21st of April and the end of September. In the Satan Valley and numerous other localities are numerous locations for storage reservoirs which could be cheaply built and made to serve a large acreage.

Nolan County.—Altitude, railroad track at Sweetwater, 2,210. In the southern part of the county the average depth of dug wells is about 40 feet. In the northern part they are of greater depth and few in number. Such as are bored, and they are few, are from 40 to 70 feet deep. The divide between the Colorado and Brazos Rivers traverses the county from east to west, and on this the wells are the deepest. All the well water on the north side of the divide is more or less impregnated with gypsum and not generally fit for use, leaving a white deposit on the ground wherever it is spilled and allowed to evaporate. It is used for irrigation in a number of small gardens and is found to be beneficial to plant life rather than otherwise. South of the divide the water is much better, and is best in the post-oak timber near the southeast corner of the county. The deepest well in the county is at the plaster of Paris factory at Sweetwater. This well is 500 feet deep. The first water was found at 150 feet, and thereafter numerous other veins were found, finally rising to within 65 feet of the surface, and the water obtained is strongly impregnated with gypsum. Drinking water is stored in cisterns. Bored wells on the divide are from 150 to 300 feet deep, having a very limited supply until the depth of 300 feet is reached. The water then rises to within 16 feet of the surface. It is thought by many that good water and possibly flowing water will be found at a depth of 800 to 1,000 feet.

There are thirty or forty locations where storage reservoirs, covering 320 to 640 acres, could be cheaply built. The soil will retain water, and seems to be excellently adapted to storage. It is the opinion of Messrs. Croan & Fisher, of Sweetwater, that if such reservoirs were built there would be no trouble whatever in disposing of water rights. A farmer, in their opinion, could afford to pay $2 per acre or more for water rent per annum. At present figures lands are worth from $2.25 to $5 per acre, but if the water for irrigation were handy they would probably increase in value to about $25 to $50 per acre.

Ragland & Beall, Sweetwater: "We have a great many common bored stock wells from 125 to 250 feet deep. The water in same for most part stands within 70 or 80 feet of the top. The wells are about 6-inch bore and cost upon an average from $1 to $1.10 per foot. The water in the northern portion of the county is impregnated more or less with gypsum. In the southern portion it is free from any unpleasant minerals. No irrigation is done from these wells. However, with a sufficient flow of water, irrigation would be very profitable, as the rainfall is not sufficient during cropping season. The wells that have been bored pass through some rock, but no great difficulty is experienced in boring any of them. We can not give any definite answer as to how deep to artesian water.

Ochiltree County.—Altitude about 2,500 feet above sea-level. Irrigation necessary about half the year. Common wells in the vicinity of Gilaloo and Ochiltree vary in depth from 190 to 220 feet. After securing the water it rises in the wells from 15 to 20 feet. At Creswell the water does not rise in the wells.

Carson County.—Panhandle City. The Fort Worth and Denver Railway made a boring here of 600 feet but failed to secure a flow of water.

Gray County.—Water in some wells at 130 feet.

Potter County.—J. C. Hatchell, Amarilla: "Water is obtained in this vicinity at an average depth of 200 feet. It rises from 20 to 80 feet and is brought to the surface by windmills. It is clear and soft, and is used for watering stock and farm purposes generally. The supply is inexhaustible to windmills."

Roberts County.—J. C. English, surveyor, Miami: "Water is obtained at a depth varying from a few feet up to 500 feet in this county. On the upland plains the shallowest well is about 100 feet and the deepest 500 feet. Sometimes an abundance of water is obtained at 100 feet, while one-half mile distant none is obtained at 300 feet."

Walker Scoggan, Canadian P. O.: "The annual rainfall is about 24 inches, falling mostly in May, July, and August. Irrigation is deemed necessary every year."

Scurry County.—A. C. Wilmeth, Snyder P. O.: "The rainfall between April and September is about 18 to 20 inches. Irrigation not necessary every year, but when needed, will be required in winter. We have no artesian wells in this county, though we thoroughly believe we can secure one by boring 300 feet or more. Our locality is furnished with water from wells about 40 feet deep, on the average. We secure water in sandstone. In one well I bored I struck water at 30 feet, a light stream; at 50 feet a bold stream, and the water rose to the first stream. I am using a 10-foot windmill to raise water for stock and irrigation. Can irrigate about 5 to 10 acres by close work and the help of the rains. Springs break out at higher points than the town, and I believe water can be secured by boring."

Ordinary wells in the county range in depth from 25 to 100 feet, and there seems to be no uniformity in any locality as to depth. Generally fresh water is obtained, but in the northeast quarter of the county the water is more or less impregnated with gypsum.

Tom Green County.—Several thousand acres in the vicinity of San Angelo are irrigated from the Concho and its tributaries. There are several very fine locations for storage reservoirs, situated conveniently for the irrigation of very large areas or land. Quite a number of gardens and small tracts of trees and vines are irrigated from windmills. The mean annual rainfall is as follows at Fort Concho: 1878, 24.84 inches; 1879, 18.54 inches; 1-80, 37.75 inches; 1881, 18.96 inches. The precipitation is greatest in May, June, July, August, and September of each year. Irrigation is highly advantageous to insure perfect success in farming, and the means for effecting it are cheap and convenient along the streams. On the uplands the well and windmill or the artesian well will have to used more or less.

Val Verde County.—At Del Rio some 3,000 acres are irrigated from the San Felipe Springs, which rise about 1¼ miles northeast of the town. Wells and windmills are used away from the water courses, and some of them have a depth of 475 feet, carrying about 175 feet of water and deemed inexhaustible to windmills.

Wheeler County.—No attempt to drill for artesian water has been made in this neighborhood. But there are several springs strong enough to rise up through a pipe held over them. The spring out on Van Horn & McKinley's ranch rises up through a pipe 14 or 15 feet, and would probably rise much higher.

SPRINGS WEST OF THE NINETY-SEVENTH MERIDIAN.

DISTRICT NO. 1.

Dimmit County.—A. Eardley, Carrizo Springs Post-Office: "A number of fine springs in the county."

Bastrop County.—B. P. Templeton, Garfield, Tex.: "There is not a living spring in this section of Bastrop county. What few there are are nothing more than wet weather seeps, that dry up in drought."

Bee County.—W. R. Hayes, Beeville: "There are no springs of any consequence, but an inexhaustible supply of water for windmills, reached at from 30 to 100 feet under the surface."

Clay County.—Mrs. Rachel D. Ivie, Myrtle, Tex.: "In this part of the county there are a number of good springs. Water is got, at from 12 to 50 feet, in abundance; mostly soft water."

Comal County.—A. Giesecke, New Braunfels: "Comal Springs, located in Comal County, near New Braunfels, very clear water, contains mineral matter, 21,000 cubic feet per minute, flows very rapidly. Drought has no effect on the volume of the water. There are several more springs in this county, but all of them are more or less affected by droughts. I could only give the names of the springs, but no other information. A great deal of boring for water has been done in this county, but no artesian water has been struck. The deepest well was bored by Christian Pfeuffer (about 600 feet) who may be able to give some information. His address is San Antonio, Tex."

Cooke County.—W. G. Robinson, Rosston, Tex.: "There is a remarkable spring of water near the surface, situate about 1 mile from Rosston. The opening is about 8 feet in diameter. The water is about 1 foot from the surface. It is not affected by dry weather nor does the water rise any higher by rains. There are other small springs near here, but I am of the opinion that they are from the drainage of the surface. The first-mentioned spring is on W. T. Berry's farm."

Greer County.—H. A. Sweet, Mangum Post Office: "In this county are the follow-

ing springs: Station Creek Spring, Spring Creek, Elm Spring. There are no artesian wells; surface water in springs, some of them of considerable volume; would fill, say 10 to 12 inch pipe, others still more. Water is obtained in ordinary wells in from 12 to 40 feet all over the county."

Hays County.—E. J. L. Green, San Marcos, Tex.: "No artesian wells in this county. The San Marcos Springs, which support the San Marcos River, are the grand springs of this section, or county. They furnish some 1,200 horse power and flow about the same all the year. Water clear as crystal."

Otto Groos, Kyle, Tex.: "The San Marcos Springs are near San Marcos. The water comes out from under a mountain and makes a good-sized river. It is evidently artesian, as the rains have no effect on the water. It always runs the same and has the same temperature all the year round."

Jacob's Well is a large spring, coming out of the bottom of a creek, through solid rock. The spring, which resembles a well, is about 8 feet diameter and goes straight down through solid rock 30 or 40 feet. It is clear as crystal and the flow of water is always the same. This spring is about 14 miles northwest from San Marcos Spring and both have the same water.

Lampasas County.—James Deering, Lampasas: "Hanna Spring yields 10,000 gallons per hour, and Hancock Spring 10,000 gallons per hour."

D. C. Thomas, Lampasas: "We have in this city three noted mineral springs, each throwing off some 2,000 gallons per minute and flowing into what is known as the Sulphur Fork of the Lampasas. These springs are somewhat celebrated for their curative properties, and I regret that I can not now send you an analysis of the waters."

These springs are not influenced by rains, there is no variation in the flow at any season.

Bandera County.—William S. Ross, Hondo Cañon Post office: "There is no artesian well in this part of the country, but plenty of springs."

Burnet County.—R. W. Cates, Burnet: "There are no artesian wells or springs of importance that I remember now."

M. J. Moseley, Shovel Mountain Post Office: "Some deep wells at Marble Falls, but none artesian, I think. Surrounding country is full of springs, many of which spring up with great force."

Louis Polk, county surveyor, Burnet: "No artesian wells in county. Mountainous sections abundantly supplied with springs. Water on the table lands found by boring from 80 to 250 feet, but water does not rise to surface, owing principally to caves in the ground to which the water rises and then flows off in the same."

Caldwell County.—E. H. Rogan, Lockhart, Tex.: "We have within the corporate limits of Lockhart seventy-five or eighty free running springs furnishing a large water supply of first quality. The San Marcos River, on the western boundary of the county, can be used for purposes of irrigation over a large extent of fertile country. With this exception we have no water in the county that can be used for irrigation."

Hardeman County.—John Wesley, Quanah Post Office: "A great many flowing springs in the west part of this county on Good Creek."

Mason County.—Calhoun & Kniveton, Fredonia, Tex.: "Barton Spring lies east of Fredonia three-quarters of a mile, Spice Rock Spring southwest 3½ miles. Barton Spring is in a lime formation and Spice Rock in granite."

Menard County.—F. M. Kitchens, Menardville: "There are springs on Survey No. 1456, W. J. Wilkinson, Fort McKavett; survey No. 1441, Alfred Streigler, Menardville, also W. L. Black and W. J. Vaughan. Robert Robinson, McKavett Springs: Clear Spring flows about 1,200 cubic feet per minute; W. L. Blacks Spring, about 300 cubic feet; McKavett Spring, about 400 cubic feet; Coglan Spring, about 100 cubic feet, and Elm Spring, 75 cubic feet per minute."

San Saba County.—S F. Ray, San Saba: "Springs owned by Thomas and R. L. Sloan, George Baker, R. C. Hart, J. H. Brown, Gabe Hart, B. H. McAlley, F. Hamrick, and E. L. Hicks, all of San Saba. E. L. Hicks irrigates 25 acres, 12 miles southeast of San Saba town. J. H. Brown runs 50-barrel roller mill. B. H. McAlley and Floyd Hamrick irrigate 15 acres each, 3 miles east of San Saba town. Thomas and R. L. Sloan irrigate 30 acres, 14 miles west of town; George Baker, 30 acres, 13 miles west, and R. C. and Gabe Hart, 15 acres, 14 miles west of town. Richland Springs not used for irrigation would supply 12 acres."

Throckmorton County.—C. E. Smith, Throckmorton Post Office: "A number of ever flowing springs."

Wilson County.—J. B. Polley, Floresville Post Office: "At Sutherland Springs and at Jackson's Gulch are large black and white sulphur Chalybeate and magnesia springs."

Wilbarger County.—C. F. Doan, Doan's Post Office: "There are large fine springs around Doan's, but none of the water is used for irrigating purposes."

Comanche County.—T. R. Hill, Comanche Post Office: "Bluff Spring, 5 miles west

of Comanche, runs out of sandrock. There are several springs in the county and usually water can be had at from 15 to 100 feet."

Burnet County.—T. A. Chamberlain, county surveyor, Burnet: "Oatmeal Springs, owned by H. Campbell; Post Oak Spring, owned by J. M. Tumlinson; Delaware Spring, by H. G. Peyton, all at Burnet, limestone water; Flat Rock Spring, owned by Herman Fuchs; Tiger Mills, also limestone water; Spicewood Spring, owned by M. B. May, Burnet, limestone water."

Bosque County.—G. M. Coston, Cranfill's Gap Post Office: "One spring at this place. I suppose it furnishes about 25 gallons per hour."

Llano County.—E. H. Alexander, Llano, Tex.: "There are springs on S. W. Kendrick pre-emption, Llano Post Office; on Nellie Bedford survey, owned by W. E. Rabb, Packsaddle, Tex.; one owned by E. Moore, Packsaddle Post Office; on survey No. 619 State school lands, owned by F. C. Wilbern, Llano, Tex.; one on section 129, Germany Immigration Company survey, owned by Joe. F. Brown, Valley Spring, Tex. The F. C. Wilbern spring rises on the top of a mountain and flows down into the valley of the Little Llano, sufficient for irrigating several acres. There are other fine springs in this county used on a small scale for irrigating."

Kerr County.—Ann E. Joy, Japonica, Tex.: "Springs are too numerous to mention, as all the water courses are fed by them and do not dry up in the summer. Those that live on the water courses have lasting water all the time; on the Divide (as it is called) they use windmills and wells."

Jack County.—T. D. Jones, Jacksborough: "Limestone water; many bold springs in the county, seemingly inexhaustible. Cost of artesian wells average $125 to $130."

Hill County.—J. O. Files, Files Post Office: "We have in places an abundance of what we call surface water, consisting of never failing springs and wells."

Bandera County.—G. T. Lincoln, Bandera, Tex.: "There is only one artesian well in the county, but there are hundreds of springs."

Duval County.—James A. Lahy, San Diego Post Office: "Springs in San Diego Creek and in Palo Blanco Creek."

Stephens County.—T. W. Brown, Breckinridge Post Office: "Several springs in the county where the water comes to the surface, but does not flow off, except in very wet weather."

Somervell County.—A. R. Fowlkes, Glen Rose Post Office: "Springs owned by William Porter, Frank Murphy, Jesse Kinsel, S. H. Brown, and J. A. Hart, with many others, furnish Squaw and Paluxy Creeks. Both flow throughout the year. Squaw Creek, the smaller one, gets very low. The water is limestone."

Maverick County.—Otto Peteler, Eagle Pass: "Rishe Spring is 13 miles east of Eagle Pass; Salado Spring 22 miles southeast; Rosita Spring 7 miles southeast, and Soucito Spring 7 miles northwest. All the springs mentioned are everlasting. Water very good for drinking, but the flow is very weak and the water sinks into the ground at a short distance from the spring."

McLennan County.—Andrew Goddard, Waco, Tex.: "There are twelve strong-flowing springs in and near Waco; five springs near Bosqueville; one fine spring near Conger's place, and a large spring near Patrick. Near Bosqueville is an alum well."

Jeff Davis County.—C. H. Merriman, Pecos City: "From Phanton Lake due north nearly 12 miles, James Edgar discovered on the open prairie a swift-running stream that had just worked its way to the surface. His attention was attracted by the waving of the grass, which shortly after disappeared from view. On closer examination he found a good-sized stream where there had been none a few hours before. Only a few yards of it are above ground."

Callahan County.—A few springs of limited capacity and liable to dry up in time of drought.

Shackelford County.—Springs are numerous and lasting. None are used for purposes of irrigation.

Lynn County.—C. H. Earnest, Colorado: "Quite a number of fresh-water lakes and two salt lakes."

Crosby County.—C. H. Earnest, Colorado, Tex.: "Large springs are very numerous."

Eastland County.—J. E. Luse, Cisco, Tex., says: "Springs of this county are of limited capacity, and a majority of them are unreliable in time of drought. A few might on a limited scale be used for irrigation. First sulphur spring about 4 miles northeast of Cisco, about 15 feet above bed of creek. Will water 100 head of cattle all the year round. A cow will daily consume about 10 gallons. About one-half the water is consumed."

Coon Spring, 1¼ miles from Cisco, in bed of creek, 4,800 gallons drawn daily would exhaust the spring. A small dam thrown across the creek would irrigate a limited acreage.

A number of mineral, sulphur, and pure-water springs, about 5 miles southeast of Cisco, in a ravine. They now water about 1,000 head of cattle. The place is known as Leon Creek, and is visited as a health resort. A dam thrown across the ravine

would store a considerable quantity of water that could be carried to some lands below. McHughes spring, 5 miles east of Cisco, is a strong spring so situated that it could be stored, but the land below it is considered worthless for agricultural purposes.

Other springs in the county are Mulberry Bear, Shinoak, Ellison, etc., all of very limited capacity.

San Saba County.—At the town of San Saba is a large spring, affording some 500 cubic feet of water per minute, and in less than 100 yards from its source is a fall of some 18 feet, where its power is harnessed to a fine roller mill, of a capacity of some 50 barrels of flour per day. A corn mill and cotton gin are also operated by the same power. This stream is only about 1 mile in length, but such is the rapidity of its descent that one or two other dams could be successfully built, and the water thus be used again and again before it reaches the lovely San Saba River, less than half a mile on an air line from its source.

Our great springs are artesian. The outflow in most instances is slightly greater in the summer months than in the winter. Local rains have no effect upon them, their temperature is usually about 70 degrees, showing that they have about the same source and run nearly the same depth below the surface.

There are no less than twenty to twenty-five large springs within the bounds of the county, and there are hundreds of other smaller springs, besides the Colorado and San Saba rivers, and some dozen or more fine creeks, which flow from January to January. There is not a better watered section in this state or elsewhere, as to that matter.

Uvalde county.—M. L. Follette (postmaster at Good Luck), sends the following list of springs, "which flow with great force and large volume:"

Spring.	Owner.	Location.
Blush Creek	Rev. R. Galbraith	Montello post office.
Gen. Baylor's	....	Do.
Ranch Creek	J. Jennings	Do.
Live Oak	....	Near Good Luck post office.
Upper Sycamore	Mr. Bjornsen	Do.
Falling	Captain Follette	
Indian	G. K. Chinn	
Spring on Middle Creek	....	

"Ordinary springs not mentioned."

SPRINGS IN DISTRICT NO. 2.

Borden County.—Anthony Blum, Durham, Tex.: "Numerous springs of clear, soft water come to the surface at intervals. The same water is obtained in spots from a few feet to 20 feet deep. The flow is constant, though not very great; have no method of measuring it."

Cottle County.—O. Dumont, Otta post office: "We have many large springs; flow gypsum or salt water. There is no water here that could be used for irrigation purposes; it is not pure enough."

Crosby County.—(Altitude 2,600) H. C. Smith, Mount Blanco, Tex.: "On section 24, State land, two large springs; on section 1, E. Co. S. L. one large spring; on section 42, Houston and Great Northern Railroad, one large spring. I am satisfied that if the water of above-mentioned springs were confined it would rise to the surface of the plain a height of 250 or 300 feet. These springs afford a great deal of water and come to the surface with great force, throwing up a fine quality of very fine, sharp sand."

Donley County.—James H. Parks, Clarendon, Tex.: "There are numerous springs and good flowing water courses in this and adjoining counties. Some of these springs have been utilized for irrigating purposes and may perhaps come within your scope of inquiry. Those used have been carried out by open ditches, and some of them have proven satisfactory. About 100 to 150 good bold springs in this and adjoining counties."

Edwards County.—An abundance of fine flowing springs.

Fisher County.—W. C. Breedlove, Roby: "The springs all break out in the bed of 'branches,' and the most of them go dry when there is a drought."

E. D. Strang, Fisher post office: "There are a few wet-weather springs along Double Mountain Fork of Brazos and Clear Fork, but with a thorough knowledge of the country I can say there are not six living springs in the county.

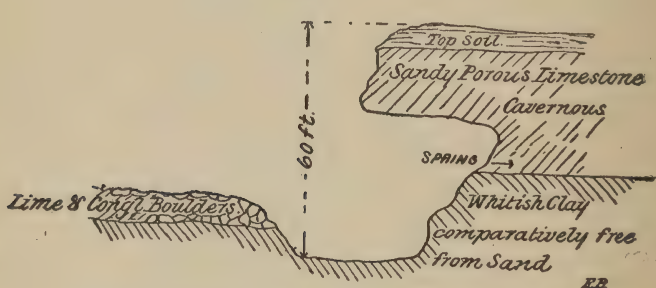
Hall County.—Alex. Stine, Salisbury post office: "Springs are abundant and along the heads of the creeks and breaks."

Hartley County.—C. F. Cacklin, Hartley post office: "There are no known springs, lakes, or rivers that can be made available for irrigation. Ten miles west of this place, in the Rila Blanca Cañon, water in several places springs from the ground, and much of it is subirrigated and still further down running water. In wet seasons the many lakes hold water the most of the year, and the general lay of the country makes it possible to use these thousands of lakes or basins for storage purposes."

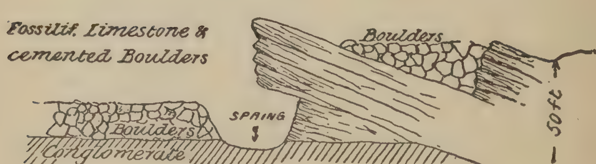
Howard County.—The Big Spring, 2 miles south of the town of Big Spring, on section 7, block 32, township 1 south, is formed in a fossiliferous limestone ledge dipping westward. It lies in a water course which, in the course of time, has been cut through by the rush of waters from above. As this ledge is formed of small flinty nodules, loosely cemented, every heavy rainfall breaks off a number, which are dropped into the pool below. Underneath this limestone ledge lies a layer of gravel, a conglomerate as hard as flint. Whether this layer of conglomerate was fractured when the upheaval took place that tilted the limestone ledge, or whether the churning action of the torrents that pour over the ledge at times, bored a hole through this conglomerate, I will not undertake to determine, but will add as a matter of information that during last May the torrent resulting from a three-hours' rain lifted at least 40 tons of bowlders, some weighing 300 pounds, out of the spring. The fall of the torrent, perpendicular, is about 35 feet. The spring has a diameter of 40 feet, and normally carries 12 feet of water. Its altitude is 2,395 feet. A railway steam pump extracts daily 100,000 gallons, a number 9 Knowles being used. The water is pumped one-half mile to a ridge between the town and the spring, and then by gravity flows the remainder of the distance. As the spring lies 150 feet above the town it could be syphoned quite easily. When not pumped there is an overflow of the spring, but the pump keeps it below overflow.

Moss Spring, on section 21, township 1, south, block 31, about 6 miles southeast from Big Spring, comes through a small cavern of sandy porous, nearly limestone. It has a perpetual flow, equivalent to that of a 4 or 6 inch pipe. It is also in a draw, and has below it a large deep pool and issuing from this a creek one-half mile long, which is then lost in the sand.

SECTION OF MOSS SPRING



SECTION OF BIG SPRING



The two springs differ about 150 to 200 feet in altitude. The limestone and conglomerate of Big Springs seems to be identical with the same material found in the wells at Marienfeld, 20 miles west and 300 feet higher. The porous sandy limestone of the Moss Spring, resembles that of the artesian well at Odessa, at a depth of 800 feet.

In the vicinity of Moss Spring are several smaller ones, and north of Big Spring 13 miles, is Wild Horse Spring, affording a limited supply, and remarkable perhaps only for the fact that the bones of an elephant or mastodon have been unearthed there.

Irion County.—J. M. Carson, Sherwood, Tex.: "Spring Creek, Dove Creek, and South Concho start out with large springs, which irrigate several large farms each."

(Memorandum by editor.—These springs lie on the southern foot of the Staked Plain.)

"Spring Creek irrigates about 700 acres."

Knox County.—George S. Benedict, Goree, Tex.: "We have plenty of springs in this county."

Lipscombe County.—E. C. Gray, Higgins, Tex.: "Numerous springs abound, which seem to be of artesian nature. Wherever the water has been confined it raised to overflow the curbing in which it was confined."

Martin County (altitude 2,700 feet).—A soda spring and a sulphur spring, both of limited capacity, in Sulphur Draw. Mustang Spring, 4 miles south of Texas and Pacific Railway, on Mustang Draw, is a leak, probably, from underground stream in this draw, silted up, but water in abundance at 1 or 2 feet. It is thought that there is water enough to irrigate a section or two of land.

Midland County.—One spring on Chicago ranch and Peck Spring 18 miles south of Midland town. Neither afford sufficient water for purposes of irrigation.

Mitchell County.—Springs of sufficient volume for irrigation, or so located that they could be used to advantage, are rare. The only spring worthy of special mention is known as "seven wells." It is located at the junction of the two Champion Creeks. Right at this junction a bed of gray very coarse friable sandstone, containing a vast number of quartz and other pebbles, crosses the creek at right angles. At times there is water in the creeks, which, also meeting at right angles on this sandstone bed, form eddies, which, picking the loose pebbles, had the effect of drilling wells. Altogether there are from twenty to thirty perforations in the sand rock, some extending downward only 3 or 4 feet, while others go down 70 to 90 feet. The holes are about 3 to 4 feet diameter at the surface, but increase in diameter downward. A large part of the sand ledge has been carried away, and in high water there is a fall of 15 or 20 feet. Several of the holes have penetrated clear through the sandstone and clay below, and from these there issues a small stream of water running into a small lake below. If the quantity were sufficient, it is yet a question as to whether there is any land suitable for cultivation below.

Nolan County.—Springs few and far between in wet weather, and noted for their absence in time of drought.

Ochiltree County.—(Altitude, 2,500.) W. J. Todd, Ochiltree post-office: "Have several good springs in the county, but I know nothing of the character of the water."

Issac A. Curry, Gilaloo post office: "Gilaloo Creek is unquestionably fed by strong springs. The source is a pool, and a strong stream starts from the outlet."

Gray County.—(Altitude, 3,000.) Numerous large springs, some of them 100 feet diameter and very deep. Water clear as crystal.

Potter County. J. C. Hatchell, Amarillo, Tex.: "The springs in this county lie in the cañons 100 to 200 feet or more below the plain."

Roberts County.—There is considerable spring water on the Canadian River and the creeks that make into it. The bottom of the river and the creeks are about 500 feet below the Staked Plain. These springs are artesian in character, because they are much stronger in winter when no rain falls, or nearly none. The ground here has not been wet for two or three years, that is, soaked with water, but the flow of spring water has not been lessened in the least.

Val Verde County.—W. K. Jones, Del Rio, county judge: "The San Felipe Springs rise 1¼ miles northeast of the town of Del Rio; 3,000 acres are irrigated from one of them. They unite about 500 yards from their sources and form a nice creek. The springs are about 400 yards apart."

Wheeler County.—D. W. Davies, Mobeetie post office: "Springs on section 58, block A 5, owned by D. W. Vanhorn; on section 40, block A 9, owned by Mark Husselby; section —, block A 5, owned by W. W. Anderson; section 6, J. Pointevent, surveys owned by J. R. Wright; on section 58, block A 4, Jenkin E. Jones, all of Mobeetie, Tex. The Vanhorn and Anderson springs are the most noted of those given, being about 7 or 8 feet in diameter. Water pure and good. Appears to be boiling perpendicularly from the earth with slight deposits of white sand. Wet or dry seasons do not appear to affect the volume of water."

Mark Huselby, Mobeetie post office.—"There has been no artesian wells sunk or bored here. There is a well in Carson County 320 feet deep; water raised 80 feet in well. There is strong evidence of artesian water hereabouts, as there are three large springs within radius of 10 miles of this place that will carry water 10 to 20 feet above the level."

One spring 8 miles north of Mobeetie raises water in a pipe 12 feet from surface.

DISTRICT NO. 3 AND REGION.

Brewster County.—H. Van Sickle, Alpine, Tex.: "No springs or subterranean water courses."

Jeff Davis County.—Four springs at Fort Davis are largely used for irrigation of gardens. In the vicinity of the town there is an abundance of water slightly alkaline, which can be had at a depth of 6 to 20 feet. Windmills are extensively used and a large acreage in gardens is thus irrigated.

Horn's spring, on Boulder Peak, located by Captain Livermore, at an altitude of 10,000 feet. This spring is about 2,000 feet above any other point in the country for many miles. It waters about 1,500 head of cattle and is not known to vary in supply, though the creeks at the base of the mountain frequently dry out. This spring lies just 200 feet below an isolated peak, forming the top of the mountain, and is on the southwest side of the same. This mountain forms the watershed between the Rio Grande and the Pecos. On the west side are barrel springs and several others of minor capacity, which are permanent and are used for watering cattle.

On the east side of the Davis Mountains are a great number of springs. Phantom Lake (described elsewhere as an underground river) would irrigate 4,000 to 5,000 acres, being a solid body of water running like a mill race, and having a diameter of 6 by 10 feet. Victoria Springs, coming out 4 miles below to the east, are the same water and are used to irrigate between 3,000 and 4,000 acres. There are a great number of other but smaller springs in the same locality, which is on the north side of Davis range. None of the springs on this side of the range have been known to fail in their supply, while the springs on the southeast side often dry out.

On the road from Toyah to Fort Davis, on the Clayton Ranch, is a large spring sufficient for 20 acres.

Six miles east of Phantom Lake, lying from 600 to 1,000 feet higher than the lake, are seven large springs, and in the neighborhood at least one hundred more, which, though of small capacity, are all permanent.

Reeves County.—Nine miles south from Toyah is a spring capable of irrigating from 30 to 50 acres. Above information from interview with Pat Dolan of Fort Davis.

El Paso County.—Above the point where the Quitman Mountain range is divided by the Rio Grande, about 30 miles south of Sierra Blanca Station and 200 yards from the river, are two hot springs known as Ojo Caliente. The larger hole has water of a high temperature, slightly mineral, throwing out much gas, and is found to be several hundred feet deep. The smaller spring is about 100 yards from the larger, has also mineral properties, and is not quite so hot. The water is pleasant to drink. A rim 2 feet high has formed around each spring from matter held in solution. These springs are said to be more like wells, generally holding a uniform water line, but are said to ebb and flow. In a cañon distant about one-half mile from the springs or wells is another hot spring which flows continuously.

Pecos County.—Leon Spring is due west 9 miles from Fort Stockton. It is a hole about 60 feet in diameter, of unknown depth. Local tradition has it that 10 lariats of 40 feet each, tied together, with a heavy bowlder as a sinker, were not long enough to reach bottom. The overflow from this spring is enormous, and irrigates, it is said, about 3,000 acres. The stream issuing from it is lost in the soil. The water tastes slightly of gypsum: Monument Spring, Comanche Spring, Barilla Spring, form the heads of bold running streams that serve for purposes of irrigation, and are used for this purpose, and then lose themselves in the sandy soils.

Reeves County.—Nine miles northwest of Toyah is Petrikin Spring, having a large flow that could be used for irrigation, and 4 miles northwest of this is a strong sulphur spring. The Petrikin Spring is about 200 feet higher than Toyah and covers an area of about 15 by 25 feet, flowing a stream 2 or 3 feet wide and 1 foot deep for one-half mile, where it empties into several lakes from one-half to 1 acre in extent, and is finally lost in the soil.

Pecos County.—Comanche Spring, near Fort Stockton, is about 40 feet wide and carries about 10 feet of water. It flows 5 or 6 miles and is lost in the soil. Part of the water is used for irrigating.

From Report of State Geologist, 1888, the following:

"Of the four springs on the eastern side of the mountains (Franklin) only Monday Springs, 13 miles from El Paso, contained water in sufficient quantity for camp purposes; another, 4 miles further north, is higher up in the mountains, and its water supply had dwindled down to a few gallons in twenty-four hours. On the west, or river slope, I found a strong spring of clear cold water.

"Eagle Springs, now a well 60 feet in depth, supplying 600 head of cattle with water. This spring is in the Eagle Mountains and nearly 4,900 feet above sea level.

"The Van Horn wells (Van Horn Mountains), on the old stage road from Fort Davis to El Paso, may easily provide water for about 1,200 head of cattle, but they are the only source of water in this county. These wells are 4,800 feet above sea level.

"There are no springs or water in any shape below Van Horn wells until the water holes below Chispa Station are reached, which may supply from 600 to 800 head of cattle, but only under favorable circumstances.

"Went to camp at a water hole in the prairie 4 or 5 miles southeast of Chispa Station and about the same distance from the so-called rim rocks of the Chenati Mountains, or as this part of them is named, the Capote Mountains. There are a number of water holes in the prairie which are frequently dry.

"The spring at Viejo Pass will supply about 1,000 head of cattle. East, towards the Muerto range of the Apache Mountains, a number of wells are dug at the foot of the mountains. They all supply from a moderate depth (30 to 40 feet) water for a limited number of cattle, but have nothing to spare for irrigation.

"Near the foot of the Sawtooth Mountains, at an altitude of 6,070 feet above sea level, I found some good springs.

"Fort Davis is located on the Limpia Creek, a little stream, the source of which is about 7 or 8 miles west of here. It supplies permanent water in such quantity that it can be used for irrigation of the valley and flat east of town. The soil of this flat is excellent farming land. The harvests raised on irrigated land along the Limpia show what irrigation would do in the flats west and northeast of the fort."

TABULATION OF WELLS REPORTED

BETWEEN

THE NINETY-SEVENTH MERIDIAN OF LONGITUDE WEST FROM GREENWICH AND THE FOOTHILLS OF THE ROCKY MOUNTAINS (BEING GENERALLY THE ONE HUNDRED AND FIFTH MERIDIAN).

TABLE NO. I.—*Location, elevation, depth, cost, pressure, variation in flow.*

NORTH DAKOTA.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.	*Feet.*				*In.*		*Lbs.*	*Lbs.*			
Casselton City	Casselton	Cass	35	140	52		304		2 feet	$750	$2.50	3	8				Yes*	
Roller Mill	...do	...do	SE. ¼ 35	140	52		318		On level	831	3.00	2	22½	8			Yes.	
Devil's Lake	Devil's Lake	Ramsey					1,511	1,477		9,000	3.35		79	25		Yes.	(†)	
Ellendale	Ellendale	Dickey	12	129	63		1,087		20 feet	4,440	4.00	5	700	115		Yes.		
Grafton	Grafton	Walsh					912			3,800	4.00	8	700					
Armstrong	Grandin	Cass	28	144	49		113			150	1.50		50	13½				
Weisbecker	...do	...do	3	143	47		158			200	1.00	2	3					
Pratt	...do	...do					185			185	1.00	2	Small					
Hamilton City	Hamilton	Pembina	35	162	53		1,565	840	On level	10,150	4.50	6	16⅓	26		Yes.		
Do	Hillsboro	Trail	5	146	50		200		...do	500	2.50	6	4					
Searle	...do	...do					195			200	1.00	2	2					
Anderson	...do	...do					200			228	1.00	2	15					
Jamestown	Jamestown	Stutsman					1,486			7,100	4.75		537	95½	24			
Mayville	Mayville	Trail	32	147	52		355		On level	667	2.00	3	90	30				
Oakes City	Oakes	Dickey					853						820	120				
Do	Rutland	Sargent					600					2						
Tower City	Tower	Cass	SE. ¼ 19	140	55		685		2 feet below	500		2	10					
Stimmel	Wheatland	...do	8	139	52		381			700	1.80		4			Yes.		

SOUTH DAKOTA.

Name of well.	Town or city.	County.	Section.	Township.	Range.	Date of completion.	Total depth of well.	Above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
Railroad well	Ashton	Spink	30	118	62	1882.	925	1,250	Level	3,000	3.24		600	45				No change.
J. W. Briggs	Beaver	Miner	26	105	58	Nov. 1, 1888	162			95	.58		127					Do.
J. L. F. Johns	...do	...do	28	105	58	Aug. 16, 1887	175			194	1.12½	2	10				Yes.	Do.
Frederick	Frederick	Brown	NE. ¼ 11	127	64	May 27, 1890	1,139	1,500	24 feet	3,702	3.50	1	120	88	35			Do.
Do	Groton	...do								3,000								
P. R. Crothers	Hetland	Kingsbury	19	112	53		710		C. & N. W. R. R., on level.									
Fred G. Bolt	...do	...do	21	111	53	Sept. 10, 1889	785			$588.75	$0.75	2						

Kimball City	Kimball	Brulé	3	103	68		1,068		On level	4,500.00	4.20	6	325	20				Do.
Letcher	Letcher	Sanborn	15	105	61	Dec. 5, 1888	600		do	1,800.00	3.00		190	70				Do.
Taylor's	Meckling	Clay	26	93	57	Aug. 5, 1889	330		do	83.00	.25							
P. Olson	do	do	54	93	53		240		do	160.00	.66	2	10	15				Do.
P. Olson, jr	do	do	35	93	53		243		do	150.00	.61	2	6	6				Do.
G. W. Gilbert	do	do	28	93	53		351		do	220.00	.62	2	70	40				Do.
P. Adlamb	do	do	33	93	53		311		do	185.00	.59	2	60	40				Do.
M. Peterson	do	do	28	93	52		243			215.00	.86	2	20	15				Do.
Mitchell City	Mitchell	Davison	22	103	60	Jan. 9, 1886	546		On level	3,133.75	5.73	6	175					
Thomas Reed	Arlington	Kingsbury	25	111	53		485	1,850										
Eward Erickson	Roswell	Miner		105	57	Oct., 1889	87		do	40.00	44.00	2½				Yes		
Scotland City	Scotland	Bon Homme	8	96	58	Fall, 1885	587		23	2,054.50	3.50	4	15					
A. J. Abbott	Tyndall	do	SW. 1	93	59	Dec., 1889	646		220 below			1	40	60		Yes		
Peter Byrnne	do	do	NE. 5	93	58	Mar. 23, 1890	665		180 below	1,000.00	1.50	3	250	42		Yes		
J. P. Cooley	do	do	SE. 19	94	58	Jan., 1888	578		176 below	1,156.00	2.00	1½	7	10				Do.
Mathias Jensen	do	do	NE. 20	94	59	Apr. 6, 1889	645		200 below	700.00		1	13	45		Yes		
M. L. Snyder	do	do	31	94	58		645		200 below			2	100	40				
Tyndall City	do	do	NW. 6	94	59	July, 1888	636		On level	2,544.00	4.00	4½	552	38				Do.
A. Zeinart	do	do	SW. 34	95	59	Oct., 1889	734		92 below	850.00	1.15	2	97	36				Do.
J. E. Delaney	Vilas	Miner	NE. ¼* 27	106	57	June 20, 1889	97		On level	60.00	.75		40		40		Yes	One-third amount; casing broken.
Woonsocket	Woonsocket	Sanborn				Jan., 1890	725		do	3,820.60	4.80	6	2,750	150	120			No change.
Woonsocket City	do	do	NE. 28	107	62	Jan., 7, 1890	725		do	3,820.60	4.80	6	2,750	153	120			Do.
White Lake	White Lake	Aurora	14	103	66	Feb., 1888	1,000		5	4,000.00	4.00	4	150	35		Yes		
S. Olson	do	do	7	94	53		268			138	.51	2	1	15				Do.
E. Anderson	do	do	12	93	54		250		Level	180	.72	2	25	40				
J. L. Broatan	do	do	7	93	54		307		do	140	.46	2	10	15				Do.
N. H. Buckman	do	do					260		do	350	1.34	2	30	15				Do.
P. W. Cross	do	do	12	93	55		212		do	125	.58	2	36	15				Do.
J. Daugherty	do	do					285		do	120	.42	2	20	15				
S. Douglas	do	do					315		do	140	.44	2	40	25				Do.
W. Dure	do	do	11	93	54		290		do	125	.43	2	25	30				Do.
W. Ericson	do	do	10	93	54		263		do	1 5	.47	2	30	26				Do.
S. C. Fargo	do	do	31	93	53		310		do	450	1.45	2	20	30				Do.
S. Lane	do	do	25	93	53		245		do	130	.53	2	30	15				Do.
P. Lee	do	do	12	93	54		300		do	150	.50	2	26	25				Do.
M. Marfield	do	do	26	93	53		255		do	125	.49	2	22					
M. McAlvane	do	do					300		do	140	.46	2	30	35				Do.
D. F. Morey	do	do	35	93	54		275		do	140	.50	2	18	15				
C. Olson	do	do	28	94	54		343		do	155	.45	2	10	20				
A. Peterson	do	do	11	93	54		345		do			2	30	20				Do.
G. Peterson	do	do					345		do	175	.50	2	6	10				
P. Peterson	do	do	12	93	52		310		do	160	.50	2	10	15				Do.
A. Stephenson	do	do	12	93	54		300		do	150	.50	2	20	25				Do.
M. M. Walker	do	do	22	93	54		295		do	150	.50	1	15	15				Do.
G. W. Young	do	do	33	94	54		285		do	135	.47	2	75	40				Do.
Press Brick Co	Yankton	Yankton				Aug., 1886	595		On level	2,500.00			2,500	56	20			Do.
Asylum	do	do				Sept., 1889	672		100	2,856.00	4.25	4½	120¼†	13				Do.

* One-third.

† Slight.

TABLE NO. I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

SOUTH DAKOTA—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		Feet.			In.						
P. Johnson	Yankton	Yankton	9	93	54		280		Level	$180.00	$0.64	2	120	24			Yes	
P. Larson	do	do	10	93	54		275		do	140 00	.50	2	25	26				
F. Alsagen	Gayville	do	8	93	53		263			125	.48	2	6	20				No change.
S. Luck	do	do	9	93	54		265		do	150.00	.56	2	30	32			Yes	
J. A. Pierson	do	do					380	1,260	do	570.00	1.50	2	35	28				Do.
Stiert Ferdinand	do	do					400		30	600.00	1.50	2	50	30			Yes	Do.
C. West	do	do	13	94	54		2?8		Level	150.00	.52	2	150	60				
W. Portland Cement Co.	do	do					500		do									
Yankton City	do	do				June, 1886	615	1,300	60	2,800.00	4.50	6	900	22	18		Yes	600 per. m.
F. Osborne		do	30	94	54				10 above				6		12			
B. Hinman		do	52	94	55		500		85 above	500.00		2	8		12			
S. Hanson		do	30	94	54		305		15 above	465.00		2	15		14			
T. Nelson		do	27	94	55				do	1.00		2	5					
H. Strunk	Suburbs	do					435			500.00		2	125		32			
J. T. M. Pierce		do	31	95	56		587		90 above			2	43		17			
F. P. Hardin		do	31	94	54		286			125.00		2	16		40			
G. M. Finnotte		do	30	94	54				30 above			2	30					
A. L. Vanesdale		do	17	73	54		300					2	30					
W. Warfield		do	26	93	53		255			125.00		2	22		15			
C. Miller	Vermillion	Clay	27	93	53		270			210.00		2						
C. F. Hutton	Plankinton	Aurora	34	104	64		545		10 below	800.00		2	2½		15			
Daniel Schmidt			11	108	64		725					1	6					
Charles Wilson			23	106	65													

NEBRASKA.

Name of well.	Town or city.	County.	Section.	Township.	Range.	Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
C. W. Moss	Amelia	Holt	5	26	14	Oct. 28, 1888	79			59.25	$0.75	1½	5					No change.
T. S. Smith	do	do	10	26	14	Oct., 1888	95		Level	66.25	.69							Do.
Caldwell & Sheets	Antelope	Antelope	11	23	7	Feb., 1888	125		do	100.00	.80							

Henry Bertz	Big Spring	Keith	22	14	41	Apr. 15, 1890	375		350	290.00	.80	5						
Henry Moore	do	do	20	14	41	Oct. 1, 1887	330		300	600.00	1.80	2						Do.
Wm. T. Jordan	Bliss	Holt	20	25	11	May 14, 1889	125		80	125.00	1.00		25			Yes		One-sixth.
Flowing	Chambers	do	27	26	13		47		100	47.00	1.00				3			No change.
P. L. Baker	Cornlea	Platte	30	22	2	Fall, 1889	200		Level	200.00	1.00							
E. W. McAllister	Grand Island	Hall					375		200	375.00	1.00							
William Jakob	Hayestown	Sherman	29	13	13		140			130.00	1.00	12						
Willie Calkins	Harold	Holt	10	25	12	Dec., 1889	90			25.00	.27		1					
J. N. Lytle	Herrick	Knox	17	32	2	Jan., 1889	420			310.00	.73		50					Do.
W. G. Arnolds	Lamar	Chase	18	8	41		136			30.00	.25							
Hydraulic	Lewellan	Dawson	35	12	20	May 1, 1890	106			150.00	1.40	2						
Lisbon Town	Lisbon	Perkins	23	10	40	July 15, 1889	285			427.00	1.50	6				Yes		One-half.
C. W. Lemont	Mineola	Holt	30	32	9	1889	397		200 below.	400.00	1.00							
George Shannon	do	Holt	19	32	9	June, 1889	395		Level	400.00								No change.
C. P. Coles	Newport	Rock	30	30	17	——, 1888	20		25	20.00								
Water Works	Norfolk	Madison	26	24	1	Spring, 1888	397		Level				40					
Union Pacific R. R.	Omaha	Douglas	27	3 S.	68 W.	Dec., 1889	634	5,205		1,280.00	1.50							
D., L. and G. R. R.	do	do	33	3 S.	68 W.	Feb., 1890	624	5,210		1,225.00	1.50							
The Fenwick	Ogallala	Keith	32	13	38	1885	227	3,270		284.00	1.25	4						
Santee Agency	Mission	Knox				Mar., 1886	603			1,350.00	2.20	2½	20					No change.
John Andres	St. Helena	Cedar	9	32	2	July 3, 1887	337			300.00	.75		6				Yes.	Two-thirds
R. Wadsworth	Wayne	Wayne	34	27	1 E.	Sept. 3, 1889	286		100	286.00	1.00							
A. H. Wright	Willow Spgs	Garfield	33	22 N.	15 W.	July, 1888	307			152.00	.48							No change.
Wallis	Sidney	Cheyenne		16	52		275		500	137.50	1.25	2	125					Do.

KANSAS.

Bogue	Oberlin	Decatur	2	3	29	Fall, 1886	800	2,800		800.00	1.00		¼					No hange.
Lexington	Lexington	Clark	33	31	21	Sum'er, 1888	314		150	300.00	1.00					No.	No.	
Strains	Jamestown	Cloud	5	5 S.	5 W.													
J. R. Morton	Protection	Comanche	32	32	20	Nov., 1886	52		100									Do.
Bogue	Washington	Washington.	NE. 2	3 S.	29 W.		(1)	2,500		900.00	.78		1					Do.
Artesian	Oberlin	Decatur		2	27		1,000		100	1,000.00	1.00		(2)					
Nidigh	Cedar Bluffs	do	3	2 S.	29 W.	Oct.; 1886	184	4,000		200.00	1.08		(3)					Do.
Artesian	Walker	Ellis	14	13	16	1889	264	(4)		195.00	.73		(5)					
Artesian	Hays City	do	1 and 11	15	18	1889	262		250	200.00	.76							Do.
Artesian	do	do	1				254	2,000										
Garden City	Garden City.	Finney	18	24 S.	32	(6)	902			5,000.00	5.50							
Adams	Terrytown	do	32	21	32		100	3,000	30	100.00	1.00		(7)					Do.
Artesian	Ford	Ford	22	28 S.	23 W.	Dec. 25, 1889	112	2,400		60.00	.50							
Frederick Mueller	Wilburn	do	SW.¼ 26	29	26	Nov. 31, 1889	150			35.00	.24							
Mueller's	do	do	25	29	26	1890	80		176 below.									
C. F. Hoadley	Loyal	Garfield	32	21	29		195											

[1] 1,100 to 1,200 feet.
[2] The flow of this well is thus given: "Well flows a stream about the size of a rye straw all times."
[3] Source of supply permanent.
[4] 50 feet below sea level.
[5] The water was struck at 258 and not before. Water rose 140 feet.
[6] Never finished.
[7] Found water at 30 feet; not good. The water found at 100 feet raised to a point 15 feet below the surface of the earth, and was excellent water for all purposes.

TABLE No. I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

KANSAS—Continued.

Name of well.	Town or city.	County.	Location of well. Section.	Township.	Range.	Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds. When flow is shut off.	When flowing.	Variation in flow per minute. Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
E. Hoyt	Fremont	Graham	4	8	24	1889	50											
J. J. Rosson	Ulysses	Grant	20	29	36	Dec., 1889	80	3,000		$55.00	$0.68							
J. K. Sayre	Ensign	Gray	14	28	27	Oct. 17, 1886	219	1,800		100.00	.45							
J. White	Macomb	do	23	28	28	1885	183	2,700		300.00	1.63							
John W. Hudson	Hess	do	1	30	28	May 1, 1886	113½	2,470		170.25	.94							
Wm. McGlashen	Horace	Greeley	35	17	42	1886	8						50					No change.
Eugene Tillieux	Tribune	do					200	3,650		60.00	.30		(1)					
Peck's Opera House.	Coolidge	Hamilton				May 10, 1887	239						45				(2)	
Peck's Water-Works.	do	do				Nov. —, 1888	298½			900.00	3.00		120				20	
Do	do	do				May 1, 1890	500			900.00	1.80		90					
F. B. Nolan	do	do	25	23	43	Jan., 1889	226	45		400.00	1.76		48					Do.
Water-Works	do	do	23	23	43	Oct. 1, 1888	297½			825.00	2.00		80				(3)	
J. H. Borders	do	do	24	23 S.	43 W.	Sept., 1888	265		10 below		1.50		27				Yes	
A. W. Koerner	Syracuse	do	17	23	40		355		70 below	375.00	1.05							
Newton M. and I. Prospecting.	Newton	Harvey	10	23	1 E.	June, 1888	1,045	1,454		5,000.00	2.00							
Do	do	do	20	23	1 E.	Aug., 1888	910											
Do	do	do	16	24	1 E.	Jan., 1888	1,076			2,000.00	1.50							
Santa Fé	Lockport	Haskell	36	28	33	Not finished.	1,300	3,000		5,000.00	3.95							
Bored Well	Lakin	Kearney	30	24	36	1888	97			63.05	.65							
Andon Eliason	Spring Lake.	Meade	8	31	27	Mar., 1888	138		8 below	485.00								
Do	do	do	8	31	27	do	136		do									
Do	do	do	8	31	27	do	100											
Smoky Hill	Ellis	Ellis	11			1887	290			870.00	3.00							
Artesian	Weskau	Wallace	NE.¼ 72	14	42	Aug., 1887	149	3,825		125.00	.55							
C. W. Orr	Astor	Greeley	21	18	42 W.	1888	88											
Bored Well	Chapman	Norton	8	4	23	Apr. 15, 1886	118			60.00	.50							
George Tanner	Cawker City	Mitchell	23	6	10 W.		468	1,750	40 or 50	1,020.00	2.15							
W. H. Noale	Walnut Grove.	do	23	8	7	Aug. 15, 1878	175		100	125.00	.70							
Mrs. A. J. Little	Cess	Morton	18	35	39	Aug., 1885	190		60									

Chantilly	Lakin	Kearney		36	22	37	June 22, 1884	120	328		300.00	2.50							
J. E. Carpenter	Morton	Morton		15	33	42	July, 1887	69	3,500										
J. C. Kilbourn	do	do		4	35	40	July, 1889	190	3,000		232.50	1.75							
Richfield, No. 2	Richfield	do		17	32	41	Oct. 15, 1889	700			825.00	.50		3					
Richfield, No. 1	do	do		17	32	41	June 19, 1889	670	3,000		950.00	.50		22					
Ross Calhoun	Ness	Ness		30	18	23	1885	233	2,263										
Utica	Utica	do		23	16	26	Unfinished	336											
Cunfman	Bazine	do		16	18	21	1886	250	2,200										Do.
Surprise	Kansada	Ness		29	17	26	Fall, 1885	23	2,200		25.00	1.00							
Henry Stahl	Norton	Norton		5	4	22	June, 1885	113			90.00	.50							
John Austin	Clayton	do		10	4 S.	25 W.		8		150–200	5.00	.50						Yes	
Charles Penn	Pleasant Plains.	Osborne	SE.	22	8	11		60			30.00	.50							
E. B. Roadhouse	Osborne	do	NE.	33	6 S.	13 W.	1884	82			45.00	.50							
Sidney Viers	Alton	do		17	6	14		100			30.00	.25							
Pleasant C. and M. Co.	Osborne	do		25	6	13 W.		500			1,000.00	2.00							
W. F. Heberlein	Kill Creek	do		9	8	14	Jan., 1886	350											
Osborne Public Well.	Osborne	Osborne		17	7 S.	12 W.	1856	302											
A. B. Tucker	Kearney	Kearney		17	22	27	Oct., 1888	140		100	$100.00	$0.40							
George Dewsenberry.	Mullinville	Kiowa		35	28	20	1886	135			27.00	.20							
Palmer Well	Humboldt	Lane		30	20	28 W.	1887	226			100.00	.40							
P. Bertelsen	Harman	Lincoln		9	11	8	1889	252	1,700		237.00	.50					Yes		
Miller's Well	Winona	Logan		12	12	36 W.	Jan. 16, 1890	84		50 below	31.35	.25		40					Do.
Rodgers & Sniffen	Oakley	do	SW.¼	3	11	32	June 15, 1889	725	2,981		1,590.00	2.00							
J. Milton Sears	Elkador	do		8	15	31	1888	408			270.00	.62½							
R. P. Cooper	Meade Center.	Meade		13	31	28	Oct., 1889	180	2,450		25.00	.25							
Oliver Norman	Fowler City.	do		33	30	27	Aug., 1888	127			25.00			50					
S. M. Zortman	do	do		21	30	27	July, 1888	160			60.75	.35							
Cox's, No. 1	do	do	NE.	5	31	27	Aug. 5, 1887	142	2,476		265.00	1.25		20				Yes	
So. Westn. Sugar Co.	Meade	do		36	31	28	Mar., 1889	103	3,000		250.00								
West Plains	West Plains.	do		16	32	30	Mar., 1884	170	2,750		255.00	1.50							
Joash	Joash	do		21	30	28		113		100	100.00	.25							
Cox's, No. 2	Fowler City.	do	NE.	5	31	27	July 8, 1888	175	2,476		44.00			20			Yes		
Larned Art. Min. Well.	Larned	Pawnee		5	22	16	1888	756		Below	5,000.00			400			Yes		
William Zacharack.	do	do		2	20	20		23											
H. C. Wey	Kirwin	Phillips	NW.	3	5 S.	16 W.	Dec., 1885	514	1,820	103	1,432.56	2.00						Yes	
Alleno	Logan	do		17	4	20	Dec., 1884	350		100	500.00			5					
W. P. Burford	Cullison	Pratt		30	26	15	1889	70											
Republic Coal Co.	Scandia	Republic		16	3	4	Nov. 20, 1889	1,003			3,800.00	3.00							
Sterling Salt Co.	Sterling	Rice	SW.¼	22	21	8	July, 1888	916	1,600		2,500.00	2.40							
S. S. Merthes	Hutchinson	Reno		34	23	5		26			10.00	.30							
D. H. Budd	Enfield	Rooks		33	8 S.	20 W.	1885	235	1,800		136.00	.55							
J. V. Burroughs	Zurich	do	NW.	33	9	19	Mar., 1889	200	2,170		90.00	.40							
F. P. Hill	Stockton	do		22	9	19	Oct., 1887	184	2,100		50.00	.30					Yes		

[1] No flow. [2] Well destroyed. [3] Ceased flowing. [4] Average.

TABLE No. 1.—*Location, elevation, depth, pressure, cost, variation in flow*—Continued.

KANSAS—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first ceased.
							Feet.		*Feet.*			*In.*						
W. M. Mirick	Pleasant Dale	Rush	10	16	16	1883	218	1,700		$218.00	$1.00							
Do	La Crosse	do	16	16	17	June 2, 1887	214	1,500		160.00	.70						Yes.	
Schwabb	do	do	12	17	18 S.	Sept., 1888	267	1,900		275.00	1.00							
Atchinson, Topeka and Santa Fé R. R. Co.	Rush Centre	do	29	18	18	1887	280	2,200										
D. A. Smith	Delhi	Russell	24	11	11	1888	240			216.00	.90							
Russell Artesian	Russell	do	27	14	13		970	1,700		2,325.00	2.50							
W. C. Fore	Assaria	Saline	5		2 W.	Jan. 9, 1888	94		80	94.00	1.00					Yes.		
A. N. and C. B. Case.	Bavaria	do	3	15	4	1888	36		5									
Carlson	Wonderly	do	28	16	2 W.	1888	164		20 below	196.00	1.50							
Halls	do	do	21	16	2 W.	1887	22		10 below	22.00	1.00							
Mapes	do	do	15	16	2 W.	1887	142		20	163.00	1.00							
J. M. Helfrick	Pence	Scott	13	16	34	Aug. 11, 1887	175	3,009		155.00	1.00							
Martin Heller	Wichita	Sedgwick					1,025	1,300	40	3,400.00	2.50							
Michael Lill	Andale	do	8	26	3	Not yet completed.	90											
M. A. Low	Topeka	Seward	(1)				485			1,455.00	3.00		52					
Sugar Co.'s Well	Liberal	do	NE. 33	34	32	July, 1889	159	2,865										
T. J. McDermott.	do	do	31	33	32	Feb., 1890	180			300.00								
Do	do	do	31	34	32	Spring of 1889	201	1,000	30	175.00			15					
Chicago, Rock Island and Pacific R. R. (two wells)		Sherman	20	8	39 W.	Nov., 1888	{ 260 285 }	3,702										
C. F. Magill	Stafford	Stafford	13	24	12	Nov., 1883	51			20.00	.20		35-40			Yes.		
Lincoln and Colorado R. R.	Seguin	Thomas	13	8	3	Aug., 1888	240		2 below									
R. B. Elliott	Brewster	do	7	8	35	1888	20		30 below									
John Asley	Weskaw	Wallace	32	14 S.	42 W.	June, 1887	134	3,000		75.00	.30							
Ed. Carter	do	do		14	42	1889	140	(2)		70.00	.50							

COLORADO.

A. L. Ish			25	2	68	Sept., 1886	337	9					60					
Sterling	Sterling	Logan	32	8		Mar., 1890	210			510.00								
Do	do	Jefferson	6	4	69	1869	200	5,400				2½	(3)					
John Brown		Sagnach				Mar., 1889	185		150	425.00			35			No.	No.	
Denver Tramway Co.	Denver	Arapahoe	3	4	68	June, 1888	647 5/12					3½–5						
Wm. A. Hamell	Georgetown	Clear Creek		3	68	Jan., 1888	658					2	120	40				
R. A. Southworth	Denver	Arapahoe	6	2	67	1885	480			700.00	1.00 to 1.25		4			Ceased entirely.		
J. B. Ish	Leadville	Lake	25	2	68	Fall, 1887	400			(4)			30				Yes.	20 gallons.
Orchard	Littleton	Arapahoe	16	5	68	1888	709		160	793.10	.80		10			No.	No.	
Do	do	do	16	5	68	1889	733		100	852.52	.75		10			No.	No.	
C. Burcher		Costilla	10	37		July, 1889	1,000	7,500		2,750.00		(5)		25		No	No	
Do	Zapato	do	17	40	12	Nov., 1888	241	7,500		275.00	1.00	2	1			No.	No.	
Liberty Post Office.	Liberty	Rio Grande	13	38	9	June, 1889	225	7,500			.65		(6)	75			Yes.	Two-thirds of first flow.
Chritton, No. 1	Monte Vista	do	18	39	10	Jan., 1890	277	7,000		72.00			120			No.	No.	
Chritton, No. 2	do	do	18	39	10	Jan., 1890	277	7,000		72.00		(7)	120			No.	No.	
H. H. Marsh (two wells each).	do	do	31	38	8	Dec., 1889	109	7,600		65.00				(8)		Slight		
Streeter		Boulder	30	3	69	May, 1887	250		Level			2½						
Davis and Day	Longmont	do	36	1	67	Feb., 1890	640		50	700.00	.80	3½	Very small				Yes.	Slightly.
School Section	do	do	16	2	67	May, 1887	600	5,000		800.00	.80-1.50	6	40	(9)		No.	No.	
Do	Hygiene	do	24	3	70		965	5,000		[10]2,000.00				(11)				
Do	Boulder	do	12	1	70	Spring, 1889	400			800.00			2	5		No.	No.	
Cheyenne Wells	Cheyenne	Cheyenne	20	14	44		700	4,254										
Government	do	do	20	14	44		1,770		Level	10,000.00			(12)	(13)				
H. M. Kellogg	do	do	4	15	44	June, 1889	250			125.00	[14].30		(15)				Yes.	
Kenwood Park	Denver	Arapahoe	14	5	67													
Bloqein Julian		Prowers	11 S., W. of Lamar			Nov., 1889	150	3,760		150.00		(16)						
Albany Town Company.	Albany	do	34	27	44	1888	296											
Wilde	Denver	Arapahoe					235							(17)				

[1] Liberal, Kansas.
[2] Little over 3,000.
[3] Abundance of water; no flow; abandoned.
[4] Piping to house.
[5] There are two casings: 6-inch extends 932 feet; 7⅝-inch extends 40 to 50 feet. Struck 10 big flows of water; there is a flow coming up between the two casings.
[6] Seventy-five gallons when first struck. Third flow is shut off by second flow filling the hole below with sand; diminishes two-thirds.
[7] These two wells are just alike in flow and quantity of water; they are only cased 45 to 47 feet with 3-inch iron gas pipe.
[8] My two wells vary about 20 feet in depth; can be sunk now for $45; they rise about 18 feet above well-tubing. There are 70 or 80 other wells in Monte Vista of similar capacity. The artesian capacity of San Luis Valley is phenomenal; at 920 feet struck a flow which would irrigate 320 or more acres.
[9] It will raise water 30 feet.
[10] Not cased.
[11] We had a flow at 675 feet, but lost it and it was not recovered.
[12] No flow.
[13] Water was found at 1,770 feet, and once came to the surface, but fell back. Two other drillings have been made on same 10 acres, and struck the same strata and water.
[14] With board.
[15] Pumped at the rate of 5 gallons per minute; plenty of water. It has lowered 20 feet.
[16] Bores from 12 to 6 inches; cased with lumber; good water. Had it been properly cased water would probably come to surface.
[17] Rises 20 feet; an inexhaustible supply.

TABLE NO. I.—*Location, elevation, depth, cost, pressure, variation of flow*—Continued.

COLORADO—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Town-ship.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
Burlington Round House.	....	Kit Carson..	27	3	68	....	600	......	....	....	......	......	(1)	......	......	......	......	
W. H. Gentzler..	....	....	22	2	49	....	......		....	....	......	......	......	......	......	......	......	
Larkspur........	Larkspur...	Douglas	....	9	67	1889	560	6,667	....	....	......	......	......	......	......	......	......	
Reno Park.......	Denver	Arapahoe...	11	3	69	May, 1890	724	......	50	1,200.00	......	......	(2)	(3)	......	......	......	
Joseph Stanley ..	....	....	17	3	69	....	560	......	....	....	......	......	(4)	......	......	......	......	
Public School District 9.	....	....	5	3	68	Oct., 1887	385	......	....	....	......	......	10	2	......	......	Yes.	15 gallons.
J. Cooke, jr......	....	....	....	3	68	Apr., 1888	1,0 9$\frac{5}{12}$	......	....	....	......	2½, 5⅝	......	......	......	......	......	
State of Colorado.	....	....	36	3	68	July, 1888	802½	......	....	....	......	3½	......	......	......	......	......	
E. Reithman	....	....	1	3	68	Mar., 1884	318	......	....	....	......	4	15	......	......	......	......	
Swan Anderson..	....	....	22	3	68	Mar., 1888	488	(5)	....	....	......	2½	30	......	......	......	......	
J. W. Eespler ...	....	....	36	2	68	May, 1887	408	(6)	....	....	......	......	20	......	......	......	......	
Villa Park.......	....	....	....	3	68	1889........	......	......	40	....	......	......	(4)	......	......	......	......	
William Shellabarger.	Littleton....	Arapahoe...	11	6	69	....	600	......	....	....	......	......	1	......	......	......	......	
Mrs. B. Magnes (two wells).	Sheridan....	....	4	5	68	1888........	580	......	....	$400.00	......	......	20	......	......	......	......	
J. L. Killie	Denver	Arapahoe...	....	4	68	1888........	360	......	....	....	......	3½	......	[illegible]	......	......	......	
Fred Miller......	Ludlum	Yuma	¼, 23	4	47	Mar. 10, 1890	188	4,000	....	139.00	$0.50	......	......	......	......	......	......	
Artesian.........	Vilas	Baca	25	31	44	....	......	......	....	....	......	......	(7)	......	......	......	......	
A. C. Cauble	Wakeman ..	Phillips.....	32	7	43	Feb., 1887	90	3,800	....	48.00	.25	(8)	5–7	......	......	......	......	
P. C. Breslin	Vilas	Baca.......	28	30	44	May, 1890	157	......	....	75.00	.75	(9)	......	......	......	......	......	
Artesian.........	....	Yuma	1	4	48	July, 1886	202	......	....	150.00	......	......	(10)	......	......	......	......	
Do..........	Ludlum	....do	13	4	48	Mar., 1888	193	4,025	....	160.00	.50	(11)	(12)	......	......	......	......	
Yuma Town Well	Yuma	....do	22	2	48	....	210	4,000	....	....	......	......	(13)	......	......	......	......	
Artesian.........	Holyoke	Phillips.....	33	7	48	....	80	......	....	25.00	.25	......	......	......	......	......	......	
Do..........	La Justa....	Otero	18	25	56	Spring, 1889	47	4,000	....	....	1.25	(14)	(11)	......	......	......	......	
Do..........	Lamar	Kiowa	23	18	43	....	367	3,500	....	....	1.00	......	......	......	......	......	......	
Do..........	Water Valley	....do	32	17	45	1887........	8 or 10	2,000	....	100.00	.50-1.00	......	Did not go deep enough					
Deep Well of Sheridan Lake.	Sheridan Lake	....do	25	18	44	1887........	1,280	4,000	....	4,000.00	3.00	......	Did not flow, raised 1,000 feet and stands.					

Artesian	Seibert	Kit Carson					163						Rose 10 feet, windmill does not pump dry.					
Cheyenne	Cheyenne Wells.	Cheyenne					260			10,000.00			Pumps 2,900 gallons per hour.					
Artesian	do	do	4	15	44	Jan., 1889	250	4,200	40				(16)					
Erb	Thurman	Arapahoe	17	5	52	1889	160		40	50.00	.25–.50		Never flowed, plenty of water.					
Timber Culture	Alamosa	Conejoes	35	37	9	Apr., 1888	90	7,550		125.00	1.00		8				[17] 4	
Charles S. Moore	Stanley	Costilla	17	39	9	Oct. 5, 1889	165	7,500		240.00	1.50		60			No.	No.	
Artesian	Denver	Arapahoe	27	1	67	July, 1885	150		(18)	300.00		2½–3	20			No.	No.	
Del Norte	Del Norte	Rio Grande	30	31	40		(19)		14		(20)		(21)			No.	No.	
M. Cline	Island Station.	Arapahoe	5	2	67	Mar., 1886	280					3	5				Yes.	10 gallons.
C. N. Campbell	do	do	16	2	67	Feb., 1888	440					3	60					
Geo. C. Griffin	do	do	23	1	67	Oct., 1888	340						3					
Wm. S. Lee	do	do	23	1	67		218		20	$185.00			5				Yes.	4 gallons.
Artesian	do	do	22	1	67	1887	215						2	0	1–2	No.	No.	
Do	do	do	22	1	67	Unfinished.	340											
I. A. McCools	do	do	27	1	67		300		20 below.	200.00	$0.66⅔	4	20		20	No.	No.	
A. R. McCools	do	do	27	1	67	Aug., 1887	[22] 135		20 below.	100.00			3			No.	No.	
Jno. S. McCool	do	do	27	1	67	July, 1885	155			200.00		3	20	(23)	20	No.	No.	
Wm. Murray	do	do	27	1	67	Sept., 1887	345					[24] 3						
Fred. Reithman	do	do	25	1	67	Feb., 1887	306		35			[25] 3	2					
D. E. Young	do	do	35	1	67	Feb., 1885	316					[26] 2	5				Yes.	1 gallon.
St. Helier's Farm	do	do	20	1	67	(27)												
John Bell	Sheridan	do	33	4	68	1890	620			500.00			10					
Rock Well	Lyman	do	8	2	67	Nov., 1876	620	5,285		1,200.00	.75–$2		10	(28)			Yes.	30 gallons.
Sterling Town Well.	Sterling	Logan	32	8	52	Mar., 1890	245	4,000		800.00			(29)					
U. P. Railroad	Stout	Larimer	8	6	69	Unfinished.												
Loveland Artesian.	Loveland	do	13	5	69			5,000										
Kit Carson	Kit Carson	Bent		15	48		1,500	4,273					(30)					

1 Was flowing, but not enough when began pumping; furnishes about 400,000 gallons daily.
2 Pump.
3 Good supply.
4 No flow.
5 Twelve feet above Platte River.
6 Water rose to 100 feet from surface; 300 cased; rests on sand.
7 No flow above, but an abundance of water there. Spring water comes to surface.
8 For 12-inch under 150, fifty cents over 150 feet.
9 Ten-inch diameter.
10 The water rose about 2 feet in the flint well; there is now usually a little over 20 feet of water in the well.
11 For 6-inch for first 300 feet.
12 Does not flow. Pumped up with windmill.
13 The engineer says he can pump 120 barrels per hour for 24 hours in succession. Water is 50 feet deep. Said to have raised 16 feet.
14 Six-inch diameter.
15 Does not flow. Rises 21 feet only.
16 Plenty of clear, pure water.
17 Gallons. Pipe too short.
18 Same as Henderson, U. P. R. R. D. P.
19 Not finished; now 390 feet.
20 Four dollars for 6-inch diameter to 3-inch to finish at 500 feet.
21 Struck water at 127 feet, which came to within 3 feet of surface and still stands there.
22 At 135 feet struck a bowlder and abandoned boring.
23 Water rises 35 feet above the surface in a stand-pipe by experiment. Casing 3 by 2½ inches full depth. Perforated at bottom.
24 For 20 feet.
25 For 97 feet.
26 For 26 feet.
27 Struck water rock at 400 feet; rose to 130 feet from surface. Drilled to 730 feet; found no water. Use 14-foot windmill; abundance of water.
28 60 feet high at first, now 12. It is badly cased. With proper casing the flow would be increased.
29 Water rises within 4 feet of surface; soft and good supply. Did not drill deep enough.
30 No water.

TABLE No. I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

COLORADO—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		Feet.			In.						
Geo. R. Gooch	Minneapolis	Baca	19	30	42	July, 1888	150	3,400		$75.00		8	(1)					
Montrose Nos. 1 and 2.	Montrose	Montrose	28	49	9	1887	825	5,825		(2)			30			No.	No.	
Government	Akron	Washington		2	52	Abandoned.												
John Hess	Lamar	Prowers	[3]3			1889	309		85		[4]$1.50							
Artesian		Arapahoe	4	5	68	July, 1890	720	5,324		1,080.00	1.50		10	15	6	Yes.		2 gallons.
Fort Logan	Fort Logan	do	6	5	68	June, 1888	685	5,460		2,467.77	[5]2.50		(6)					
Chas. E. Wyman	Petersburg	do	4	5	68		600						20	15				
Mrs. M. Brantner and Jonas Brantner's heirs.	Island Station.	do	36	1	67	May, 1887	430	5,180		260.00	.65 / 1.00	3	15	19				(7)
Mrs. S. M. Black	Brighton	do	13	1	67	July, 1887	300	4,800		200.00		3	1			No.	No.	
Frank Aichelman	do	do	13	1	67	Nov., 1886	350		70	250.00		2½	⅕			No.	No.	
Andrew Hagus	do	do	24	1	67		250		25				4					
P. W. Snyder	do	do	4	1	67	Aug., 1886	406		15			3	30					
Scranton	Scranton	do	16	3	65	1887	800½		100 lower			3	(8)					
Taylor's Springs	Harrisburg	do	19	2	53	1889	10						(9)			No.	No.	
Geo. C. Griffin's	Island Station.	do	23	1	67	1885	340	5,300		300.00	.75					No.	No.	
Mrs. D. A. Stewart.	Brighton	do	32	1	66	Mar., 1888	500											
F. L. Moore	Derby	do	(10)	2	66		852		200				25		25			
Artesian	Denver	do	10	2	65								(8)					
E. L. Chatfield	Littleton	do	1	6	69	Mar., 1888	365		300	235.00	.50		10			Yes.		3 gallons.
J. L. Vanderlip	Island Station.	do	9	2	67	Nov. 19, 1885	300					3	5				Yes.	1 galloon.
H. A. Vanevery	do	do	4	2	67		300					(11)	8					
June F. Wolpert	do	do	3	2	67	Dec. 10, 1886	323					3	8				Yes.	2 gallons.
Mrs. R. Morris	do	do	4	2	67		300						45					
F. M. Morris	do	do	4	2	67		500						5					
Mrs. Saml. Brantner.	do	do	34	1	67		272		(12)			(13)	12½			No.	No.	

F. C. Fowler	do	do	34	2	67	Dec., 1887	356					(14)	3			No.	No.	
F. D. Storm	Denver	do	2	3	68	July, 1886	470						166	40				
D. A. Montague	do	do	(15)	3	68	June, 1887	444		50 lower	700.00	{ 1.00 / 6.00 }		50				Yes	40 gallons.
Globe Smelter	do	do	15	3	68	May, 1886	505	5,200		3,000.00	200.00	(16)	100	50			Yes	73 gallons.
E. M. Loomis	do	do	12	3	68	July, 1888	532		18				20	40				
Artesian	do	do	(17)	3	68	June, 1889	904	5,290		2,200.00			(18)					
J. H. Webber	do	do	15 or 22	3	68	Feb., 1888	338		12			2½, 2		5				
John Brehreny	do	do	15	3	68	Aug., 1888	346					2½, 1¼	15	5				
William H. Clark	do	do	15	3	68	June, 1887	381		10			3–2		7				
Conrad Burke	do	do	27	3	68	Aug., 1888	338		(19)			2½, 1¼	10	6				
Beaver Brook Water Co.	Denver	Arapahoe	32	3	68	Mar., 1888	502						100					
J. Q. Charles	do	do		3	68					(20)			(21)	50			Yes	
Mrs. S. M. Gleason	do	do		3	68	Mar., 1888	506		12			2½	25	12				
Windsor Block	do	do	34	3	68	Aug. 30, 1883							907				Yes	
Smith Bros	do	do	23	3	68	June, 1885	360	5,200		365.00		1½					Yes	(22)
Jacob Jones	do	do	14		68		125						8 or 10					
Rouse Junction	do	do		28	66	[23] 1885	1,250	6,180		2,000.00	{ 1.00 / 3.00 }		(24)					
Artesian	do	do	(25)	3	68	1885	300							(26)				
J. C. Hopkins	do	do	8	5	67	1888	804			2,250.00	{ 2.00 / 3.00 }	3	(27)					
J. G. Hopkins	do	do	8	5	67	Oct. 13, 1888	802					2, 3						
Wright & Pray	do	do	17	5	68	Sept., 1888	302					2½	7		10			
C. R. Gallup	do	do	2	5	68		536						10		5			
Artesian	Island Station.	do	20	1	67	Aug., 1889	730	5,300		1,300.00	{ 1.00 / 1.50 }		(28)					
Do.	Monte Vista.	Rio Grande.	31	39	8	Dec. 26, 1888	103			100.00	1.00	2	15			No.	No.	
Do.	Alamosa	Conejos	13	36	10		146	7,800		25.00			20					
W. G. Winbourn	Fort Lupton	Weld	1	1	67	May 3, 1888	904			1,200.00	{ 4.00 / 1.00 }		(29)			No.	No	

1 Not an artesian well. Struck water at 150 feet and it rose 179 feet immediately and flow failed.
2 $5,000 contract to the town. Contractors lost on the job.
3 North of Lamar.
4 No casing.
5 Not including casing.
6 Well is worked with pumping engine, 42,000 gallons daily.
7 Has failed; supposed to be leakage; had diminished about one-third.
8 At 125 feet struck a bowlder and abandoned boring.
9 More water than windmill will pump.
10 5 miles east of Derby.
11 3 for 30 feet.
12 Little lower than Denver.
13 3 for 40 feet.
14 3 for 47 feet.
15 Globeville.
16 This well has three flows: (1) 300 feet, 7⅝-inch casing; (2) 465 feet, 5⅝-inch casing; (3) 500 feet, 4¾-inch casing. Drive pipe, 10 inches in diameter; each flow cased separately.
17 Capitol Hill.
18 50 feet from surface.
19 4 inches above Platte River.
20 Between $2,000 and $3,000.
21 Was at first 68,671 pounds. When D. and F. reached the same, flow was reduced to 38, and after completion of McClelland well it had to be pumped. Pumps to fill 1,000 gallon tank in one and one-third hours.
22 Diminished about one-third since bored. About 10 artesian wells within one-half mile; all flowing freely, though the flow of all is affected by seams.
23 Abandoned.
24 Salt water came up to within 40 feet of surface; was bored for oil, but abandoned for lack of funds.
25 Line between 33 and 34.
26 Water 30 feet below surface. Pressure at first, 35 pounds; at completion, unknown. Well abandoned.
27 Water came to within 40 feet of surface. A continuous supply is obtained by pumping.
28 Water came to within 125 feet of surface. A continuous supply is obtained by pumping by windmill.
29 No flow water within 4 feet of surface.

TABLE NO. I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

COLORADO—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure, in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
J. M. Mumford	Longmont	Boulder	3	2	69	June 30, 1888	506		20	$400.00	$1.25		(1)					
Re'reat Park	Denver	Arapahoe	14	3	68	Apr., 1889	240	5,200		250.00			148+			No.	No.	
Artesian	Brighton	do	19	1	64	1886	700			1,000.00	1.25 / 1.50		25					
Do	Denver	do	27	1	70	Unfinished	1,001	5,335		[3]2,250.00	1.00 / 2.50							
Do	Lamar	Kiowa	11 SW. of Lamar.			Nov., 1889	150		80	150.00			(4)			No.	No.	
A. I. & S. Fé	Sedalia	Douglas	14	7	68	1889	650				1.50 / 2.50							
Jones	do	do	36	7	68		1,440						(5)					
Pierce & Murray	Acequia	do	33–34	6	68	1884	442	5,800					15			No.		
J. M. Fox	do	do	6	6	68		596						4			2		
Geo. Manhart	Sedalia	do	14	7	68	1887	710				1.35	2½–4	(6)					
J. W. Bowles	Littleton	Arapahoe	20	5	68	Apr., 1884	378						(7)					
Shuckhart	do	do	16	5	68	July, 1889	601	5,000		360.00			15	(8)				
Fred Bemis	do	do	16	5	68		375		30	375.00			2		3			
W. W. Chapman	do	do	22	5	68	1884	440		125	500.00			20			(9)		
Geo. J. Burnett	do	do	28	5	68	1888				[10]315.00			50	(11)		No.	No.	
David Linhart	do	do	20	5	68	1888	480		12–15	480.00			15			No.	No.	
Schoolhouse	do	do	17	5	68		520											
Oscar Lehood	do	do	15	5	68		542						25					
Mrs. G. B. Elliott	do	do	21	5	68	1888	580		40	475.00			8				(12)	
Frank Watson	Denver	do	35	2	68	Oct., 1886	420		15			(13)	150		30			
Harrington's	do	do	33	2	68	May, 1887	821	5,600		1,500.00	1.00 to 2.50	3½	(14)					
W. W. Graves	do	do	25	2	68		38½		25				30				Yes	10 gallons.
John Cline	do	do	25	2	68	Aug., 1886	407		25			(15)	30	20				
M. M. Phelps	do	do	25	2	68	Dec., 1886	445		75				50		(16)			
F. P. Watson	do	do	35	2	68	Oct., 1886	420					3	30	16–40				
American House	do	do	33	3	68	Aug., 1884	945	5,195		1,611.00			(17)					
Ph. Zang Brewing Company.	do	do	33	3	68	July, 1884	600	5,200		1,500.00		(18)	(19)					
John Wolff	do	do	8	3	68	Jan., 1887	400			300.00		(20)	40	25			Yes	85 gallons.

Ph. Zang & Co.	do	do	22	3	68	May, 1888	330		(21)				20	5				
Louis Sanguinette.	do	do	22	3	68	Feb., 1886	296		(22)			(23)	15	8				
Gov. Evans	do	do	33	3	68	Mar., 1888	375					5⅝						
Electric Illuminating Co.	do	do	27	3	68	May, 1889	629	5,100					(24)				Yes	
Anheuser-Busch Brewing Co.	do	do	33	3	68		604	5,250		755.00	1.25	3-4	(25)		--		Yes	
M. D. Clifford	do	do	(?)	3	68	Aug., 1887	175					(26)	9	4				
Artesian	do	do	34	3	68	Aug., 1884	602			1,230.00		(27)	(28)					
Sand Creek House Well.	do	do	12	3	68				(29)				10					
D. A. Montague	do	do	12	3	68	July, 1887	444		10			(30)	90		40			
Mrs. E. M. Loomis	do	do	14	3	68	Sept., 1888	504		10			(31)	75					
A. S. Lang	do	do	7	3	68		400					1½	15	3			Yes	5 gallons.
Sand Creek House.	do	do	12	3	68	Nov. 28, 1887	587		Below	450.00	.85				2			
S. Capitol Hill (artesian).	do	do	18	4	67		670			1,890.75								
Platte Land Co.	do	do	1	4	67	Mar., 1890	915					3½, 2½						
Bush & Moore	do	do	15	4	67	1888	1,103	5,600		3,500.00			(32)					
E. Capitol Hill (artesian).	do	do	7	4	67	Nov., 1888	715	5,400		2,500.00 (34)			(33)			Yes		
McMurray Bros.	do	do	30	4	67		830						(35)					
L. Dugal	do	do	6	4	67	1888	770			1,000.00			(36)					
Independence	do	do	15	3	67	July, 1888	858					2⅓, 3½	25	4				
C. C. Towle	do	do	3	3	67	Sept., 1885	561						50	(37)				
Do	do	do	6	3	67		617						40				Yes	(38)

[1] No flow; plenty of water if pumped.
[2] Per diem.
[3] Till now.
[4] Water raised within 41 feet of surface.
[5] Struck water between 200 and 300; no more found deeper.
[6] Pumped by windwill in 75-barrel tank. Supply with this pump, 75 feet down, is inexhaustible.
[7] 4 now, at first 1, often 7 at time of completion.
[8] 4-inch hole, not cased, has only 16 feet of stand pipe. Raises the water 16 feet above the surface with 11 hydrants attached.
[9] Flow diminished and has since been deepened.
[10] Besides casing.
[11] Raise 30 or 40 feet.
[12] Probably diminished. Myers reports 3 gallons.
[13] 3 inches for 50 feet, 2 inches for 150 feet.
[14] Flowed from 8 to 14 gallons at first. No flow since May, 1887. Pumped water with windmill, from 50 to 70 feet, since that time.
[15] 3 inches for 50 feet, 2 inches for 200 feet.
[16] Struck water at 445 feet; rose 32 feet; cased 57 feet.
[17] No flow now. Have just put in a pump. At completion the pressure was 15 pounds. The water is now 10 feet below surface, soft and clear.
[18] 9 inches for 20 feet.
[19] Water pumped from well by steam (no flow) was 300 gallons. Diminished considerably.
[20] 2 inches for 335 feet.
[21] 10 feet above Platte River.
[22] 12 feet above Platte River.
[23] 2½ inches for 32 feet.
[24] No flow without pumping on account of other deep wells near.
[25] The well was sunk in 1883, 314 feet, with 4-inch tubing; a large amount of water. It is now only about one-tenth of its former amount and we fill the tanks by a pump to supply boiler. There is an ample supply of water.
[26] 2½ inches for 22 feet.
[27] Cased 284 feet, 5⅝ inches. Inside casing 537¾ feet 4¼ inches.
[28] January, 1885, upper flow 7¼ per minute, lower flow 51 per minute. January, 1887, upper flow none, lower flow 7¼.
[29] 40 feet above the river.
[30] 3 inches to 34 feet, 2 inches to 57 feet.
[31] 30 feet of 4 inches, 42 feet of 3 inches.
[32] No flow.
[33] No flow because on top of hill. Increased by pumping about 100 per cent.
[34] Pump, boiler, and standpipe extra.
[35] No flow, water comes 20 feet of surface.
[66] No flow, water comes 70 feet of surface.
[37] Rises 15 feet.
[83] 75 gallons last flow, now 40 gallons. Throws water 25 feet high.

TABLE NO. 1.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

COLORADO—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
Platte Land Co	Denver	Arapahoe	27	3	67	May, 1889	881	......	......	......	......	4½, 3½, 2½	15	......	......	......	......	
Do	do	do	33	2	67	Mar., 1890	828½	......	......	......	$1½, 1⅜	3½, 2½	20	......	10	Yes	......	
Mrs. C. H. Cook, No. 2.	do	do	31	2	67	......	500	......	......	......	......	3	40	......	(1)	......	......	
David Walport	do	do	19	2	67	......	600	......	......	......	......	......	(2)	......	......	......	......	
G. W. Sigler	do	do	8	2	67	......	300	......	......	......	......	[3] 3	50	(4)	......	......	......	
G. Wooley	do	do	26	2	67	Sept., 1886	316	......	......	......	......	......	30	......	......	......	Yes	5 gallons.
J. C. Knowles	do	do	35	2	67	June, 1887	416	......	......	......	......	......	90	......	......	......	Yes	10 gallons.
John J. Brewer	do	do	18	2	67	Apr., 1886	322	......	......	......	......	......	20	......	......	......	......	
Mrs. C. H. Cook, No. 1.	do	do	31	2	67	Feb., 1887	302	......	......	......	......	......	52	......	......	......	......	
Platte Land Co	do	do	23	2	67	Jan., 1890	856	......	......	......	......	3½, 2½	10	......	......	......	......	
Upper Well on Cherry Hill Farm.	do	do	31	2	67	July, 1887	521	......	(5)	$1.000.00	(6)	......	10	......	......	......	(7)	
Lower Well on Cherry Hill Farm.	do	do	31	2	67	Mar., 1887	295	......	(5)	700.00	2.00	......	60	......	......	......	(8)	
J. O. Lawton	do	do	34	4	68	Oct., 1888	565	......	......	......	......	3½, 2½	20	......	......	......	......	
Artesian	do	do	33	3	68	May, 1884	609	5,220	......	950.00	......	......	(9)	......	......	......	(10)	
Bonita	do	do	12	5	68	Apr., 1889	725	5,400	......	[11] 725.50	1.00	3	80	......	......	No.	No	
Levick	do	do	28	5	68	......	......	......	......	......	......	......	10	10	......	......	......	
Jo Playter	do	do	5	5	68	......	550	......	......	......	......	......	10	......	......	......	10	(12)
Dr. R. F. Price	do	do	33	5	68	......	......	......	......	......	......	......	(13)	......	......	......	(10)	
D. M. Richards	do	do	12	5	68	May, 1889	725	......	100	......	......	......	70	......	(14)	......	......	
C. A. Olin	do	do	1	5	68	Sept., 1887	450	......	......	......	......	......	180	60	......	......	......	
Military Post	do	do	6	5	68	May, 1888	685	......	......	......	......	......	......	......	......	......	......	
Artesian	do	do	34	4	68	Aug., 1888	565	......	50–60	600.00	......	......	20	......	......	No	No	
A. C. Fisk	do	do	26	4	68	......	700	......	......	1,265.00	......	......	......	......	......	......	......	
University Park	do	do	25	4	68	1886	740	5,300	......	1,000.00	1.00	......	(15)	......	......	......	......	
Artesian	do	do	1	4	68	1888	355	......	200	[17] 800.00	......	......	(16)	......	......	......	......	

Rosavale	4 miles south of Colfax.	Custer	27	4	68	1886	627	5,284		1,250.00	1.75		7	7			4	
Artesian	Denver	Arapahoe	4	4	68	1888	636	5,230			2.00		(18)				Yes.	
Do	do	do	34	3	68	June, 1884	662	5,200		1,650.00	2.50		(19)				Yes.	
Windsor Artesian	do	do	34	3	68	Aug., 1883	997 7/12			4,000.00								
Artesian	do	do	24	2	68	Oct., 1885	325	5,000		275.00								
Solomon Cline	do	do	5	2	67	Mar., 1886	416						6				3	
Littleton Heights	Littleton	do	16	5	68	May, 1890	810		30				16					
Frank Cayley	do	do	30	5	68								1+					
Chas. Moore	do	do	3	5	68		675											
John Curtis	do	do	28–29	5	68	1889	535						5					
H. H. Curtis, jr.	Littleton	Arapahoe	28	5	68	1889	328		80–90	635.00	1.00	2½						
H. H. Curtis, sr	do	do	28	5	68	1884	340		80 or 90	$250.00		2½	20			Yes		
Cutter, Brown, Horne & Carey.	do	do	12	5	68		710		125		$1.35		16 45	50			Yes	11 gallons.
Peter Magnes	do	do	30	5	68	1889	258											
J. B. Mayers	do	do	16	5	68		520						12					
Hotel Well	do	do	17	5	68		510											
J. B. Mayers	do	do	16	5	68		265											
Do	do	do	16	5	68		375						[20]15					
J. B. Myers	do	do	16	5	68		510						25				Yes	10 gallons.
Do	do	do	21	5	68		635						25	15				
Peter Magnes	do	do	30	5	68		365						10	5				
W. G. Sprague	do	do	16	5	68	1888	550		50				36					
Levi Palmer	do	do	29	5	68		301		20	376.00	1.00		[21]6				Yes	
Charles E. Hill	do	do	19	5	68	May, 1889	467						10	(22)				
D. W. Hunter	do	do	19	5	68	Oct., 1889	500					3½	20					
Orchard Grove	do	do	20	5	68	Mar., 1881	525		(23)	1,092.00		3½–2½	16					
R. I. Spottswood	do	do	19	5	68	Nov., 1888	287	5,000		287.00	1.00		9					
Wilde	Denver	do					235						25			Yes		5 gallons.
A. E. Meek	do	do	30	1	66		300			300.00			(24)					
Do	do	do	13	1	66		800		(25)	800.00			5	10or12			Yes	
O. L. Bright	do	do	1	3	69	Mar., 1888	908			1,300.00	{ 1.00 2.00 }	2½	(26)					
J. H. Moser	do	do	Clear Creek, June			July, 1888	494					3½	(27)			Yes		(28)

[1] Raised 60 feet.
[2] 120 gallons per minute, June, 1888, 60 per minute, water raised to 50 feet.
[3] For 25 feet.
[4] Pressure 50 feet.
[5] About 10 feet, below Denver.
[6] $1 for 495 feet; $1.50 to finish.
[7] At first flowed well and had good pressure; nearly failed, then cleared and regained half flow.
[8] Failed about one-half.
[9] No flow; use steam pump; comes within 20 feet of surface.
[10] Some.
[11] With our own time.
[12] Now nothing; pumped; very slight flow.
[13] Was good well; insufficient casing.
[14] Will raise 30 feet or 40 feet at least.
[15] Ceased flowing in about three months.
[16] Comes within 50 feet of surface and is pumped; no flow.
[17] Including windmill, $1.00.
[18] At first about 100,000 gallons in twenty-four hours; slight flow now.
[19] No flow; pump 100 feet below surface; abundance of pure, clear water.
[20] Water rises 18 feet.
[21] Was 6. Has diminished. Not cased. Stand pipe to bed rock.
[22] Water rises 30 feet above surface. Has diminished, and since deepened.
[23] Well 20 feet lower than Denver South Park depot, Littleton Station.
[24] Water struck below sandstone and shale, and rises about 20 feet. An everlasting supply.
[25] About 40 feet below Barr; below B. Canal.
[26] To 25 feet of surface. Pump 75 barrels by windmill; no effect on well. Struck inside of 170 feet.
[27] Never flowed. Water rose within 24 feet of surface; after six months, within 55 feet.
[28] Pressure at completion was 20 pounds; is now 30 pounds.

TABLE No I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

COLORADO—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		Feet.			In.						
Greeley City Public Well.	Greeley	Weld	5	5	65	1884	2,300	4,779		$8,000.00	(1)		(2)				Yes	
Gov. B. H. Eaton	do	do	31	7	65		970	4,850					(3)	(4)				
Evans' Town	Evans	do	31	5	65		(5)	4,636										
Artesian	Greeley	do		5	65	(6)	1,165						40				Yes	
Do	Windsor	do	12	6	68	Apr., 1887	350			580.00	$1.50							
Florence Soda	Florence	Fremont	14	19	69	June, 1889	(7)		50 below				1,000			No	No	
Florence Oil and Refining Co.	do	do		19	69	Nov., 1889	(8)	5,200					700					
Cañon City Oil Co. Well No. 1.	Stump	do	(9)	18	70	Fall, 1883-4-5	1,600	5,280		10,000.00	6.50		(10)				Yes.	
Thatcher	Hoehne	Las Animas		29	60	Mar., 1885	936		Same grade				(11)			No.	No.	
J. R. Fariss	Pueblo	Pueblo	36	20	65		1,400			3,500.00		3	½	60		No.	No.	
Small's Timber Claim.	do	do	17	21	65	Oct., 1888	772	4,860		1,800.00	2.00	4½	2½				Yes.	Slightly.
Columbia Heights	do	do	9	21	65	Aug., 1888	789			2,500.00	.50	5⅝	300			No.		Little.
Do	do	do	9	21	65		782		75				3-5					
Colorado Coal and Iron Co's.	do	do	12	21	65	1881	1,260		10	4,000.00			20-25	15		No.	No.	
Mineral Park	do	do	35	20	65	1880	1,150	4,753					3			No.	No.	
Clark's Mineral Spring Co.	do	do	1	21	65	1880	1,402	4,700		8,000.00	.30		87+	60		No.	No.	
Chas. Glynn	Henry'	Conejos	14	36	9	1890	200			35.00	20-75	3-6	22½				Yes.	Slight.
Legion (8 wells)	La Jara	do	1 and 2	35	9	1889	100-175	7,600		40 each		3				No.	No.	
S. E. Newcomb's Ranch (17 wells)	do	do					140-260			25 each		3				No	No.	
Alamosa Town	Alamosa	do	10	37	10	Sept., 1889	850	9,400		1,865.00	80-2.10	6-8	1,000			No	No.	
Ormand	La Jara	do	27	35	9	Feb., 1889	56	7,609		81.00	1.50	3	{250 / 400}			No	No	
Colorado Springs	Colorado Springs.	El Paso		14	66		1,120	(12)										
			1	3	70	1875	158	5,325										

NEW MEXICO.

C. Petroleum Co	Fort Wingate.	Bernalillo	16	15 N	17 W													
Santa Fé	Santa Fé	Santa Fé				Apr., 1890	1,115		On level	$3,500	$3.00							
Deming Artesian	Deming	Grant	34	23	9 W		980	4,300										
Development Co.	Las Vegas	San Miguel					1,860	6,441		7,000	3.50							
Public	Raton	Colfax				Dec. 15, 1887	1,878			7,851	3.00							
Raton Artesian	do	do	25	31 N	23 E		1,878	6,800		7,851	3.00	6						
Raton	do	do				Dec., 1887	1,872	6,700		9,000	3.00							
Turner	Springer [21]	do					250	5,660					220					

WYOMING.

Cheyenne City	Cheyenne	Laramie					1,145											
City Works	Rawlins	Carbon					525					8						

TEXAS.

S. O. Bulverde	Mecke	Bexar				Jan. 20, 1889	365	1,600		$800.00	$.60							
	Utopia	Uvalde				Aug., 1886	102			205.00	2.00	6						
Addison		Somervell				Nov. 15, 1885	337			500.00	1.25	6	10					No change.
	Glen Rose	do				1884	79			100.00	1.00	½	10					Do.
No. 1	Victoria	Victoria				June, 1888	956											
No. 2	do	do				do	853			3,000 to			70 to			Yes		
No. 3	do	do				do	815			5,000			200					
W. H. Belcher	Pidcock Ranch.	Coryell				Jan., 1886	290	2,500		500.00	1.00	6	2½					
West End Artesian.	San Antonio	Bexar				1889	260	650		500.00	1.00	7	150					Do.
M. E. Dlandt	Yorktown	De Witt				1887	66					2						
Water Works	Fort Worth	Tarrant				Not completed	2,000	650		16,000.00	8.00	10						Do.
Household	Paluxy	Hood				1886	275	1,200		275.00	1.00	6	300			Yes.		
W.T. Farnbrough	Wayland	Stephens					150		On level	150.00	.50	6	9			Yes	Yes.	

[1] Water was struck at one-half the depth and overflowed. No water was found at the greater depth. Other wells have been bored 1,150 feet 4 inches. $2,500.

[2] As the number of wells increased the flow decreased. Now all have to be pumped, and the head was lowered 40 feet below surface.

[3] No flow.

[4] Water to 18 feet of surface.

[5] Water at 1,125. In other respects a duplicate of the Greeley wells. Had no effect on those wells.

[6] Eight wells from 1885–1888. All duplicates of the first. No effect of one on another was noticed till Hunter's well began pumping. All the wells are pumped by water motor, steam power, or windmills.

[7] About 800.

[8] One thousand feet to water. Well is much deeper. Probable cost to water $4,000.

[9] Near corner common to 23, 24, 25–26.

[10] Flow was 700 gallons. Pipe was drawn, well caved. A small flow issues yet as a spring.

[11] Abandoned on account of disagreement of city council.

[12] The Turner well is reported as being the first flowing or genuine artesian well in the Territory. Water was struck on the 19th of July, 1890, after the close of the first field investigation.

TABLE 1.—*Location, elevation, deyth, cost, pressure, variation in flow*—Continued.

TEXAS—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
Center Point	Jacksboro	Jack				May, 1886	200			200.00		6						
Ref. & Can. Co.	Denton	Denton				1889	550		20			6	6					
Cotulla	Cotulla	La Salle				1885	852	750		2,500.00	3.00							No change.
Kinkaid (3 wells)	Oakalla	Burnett				1886 or 1887	100	1,200				6	30					Do.
C. Pettit	Faimer	Young					132	2,250										
W. Farnbrough	Wayland	Stephens				May 25, 1888	156			150.00	.75		9					Do.
J. R. Lane's	Files	Hill				1887	123			83.00			3		10			
A. Jasper	Jacksboro'	Jack				Oct., 1889	96			100.00	.75	6						Do.
A. E. Burge	Japonica	Kerr				1886		3,000		400.00								
W. E. Rabb	Pack Saddle	Llano				1888	200	1,200										
Waldrip	Waldrip	McCulloch				1888	220	1,500										
Moore's Artesian	Waco	McLennan					1,852			6,500.00	3.00		347	60				
W. A. Fitch	Eagle Pass	Maverick				Not complete	1,140	310										
Gordon Co.	Gordon	Palo Pinto				Sept. 1, 1880	485	3,000		800.00	1.75		1	10				
Water Works	Weatherford	Parker				Nov. 1, 1889	440		47	4,000.00	.75							
L. L. Shield	Trickham	Coleman				1888	220			400.00	1.00	6						
J. F. Meek	Piddock Ranch.	Coryell				July 15, 1889	252			200.00	1.00							
L. McCleskey	King	do		1		Apr. —, 1887	240			240.00	1.00	6	2					
Davidson	Pecan Grove	do				1886	220	600		253.60	1.00	6						
Do.	Gatesville	do				Oct. —, 1888	500 to 550		15 or 20	500.00		6	2 to 20					
T. and P. R. R. Well.	Denton	Denton				1887	41 to 600											
Alliance Milling Co.	do	do				1887												
Denton Ice Co.	do	do				1887												
Denton Mill and Elevator.	do	do				1887												
William Eckhard	Yorktown	De Witt				July —, 1884	64		6 below	60.00	.75		7 and 8					
S. D. Frazier	Carrizo Springs.	Dimmit	2			Oct. —, 1884	165			330.00	1.50		40					
Lauderdale	Lauderdale	Erath				1885	128			100.00	.70							

T. and P. Coal Co.	Thurber	do					960										
A. J. Glenn	Bluff Dale	do				Spring, 1885.	165		10 below	400.00	2.00						
Tom A. and J. W. De Vilbiss (3 wells).	Reep	Frio					158		50 below	273.00		3 to 6	3½				
							260			527.50			8½				
							391			910.50			6				
Dr. J. K. P. Green	Rancho	Gonzales					130			400.00	2.00		3				
Henry Shafer (2 wells).		Goliad					60			150.00							
Do	Sherman	Grayson				May 2, 1890	250			750.00	3.00		138				
Edw. L. Bridges	Navasota	Grimes				July —, 1887	250	290		1,800.00							
Do	do	do				May 10, 1890	830			2,500.00							
Archer City well	Archer	Archer									2.10	6					
Nic Blunizer	Pleasanton	Atascosa					350			600.00			10				
Barnes Well	San Antonio	Bexar															
Kopper		Bosque										6					
T. F. Lockett	Morgan	do										6					
Chrystal Ice and Manufacturing Company.	San Antonio	Bexar					650	683		2,000.00			840				
Do	do	do					815						400				
Do	do	do					650						840				
Do	do	do											100				
Carol ne Kampman.	do	do					465	683		1,300.00	2.79		$17\frac{36}{100}$				
F. M. Rowe	do	do					675	683									
J. J. Lumpkin	Meridian	Bosque					450	791		600.00	1.33		45				
City of Meridian	do	do					580	791		1,000.00	1.72		24				
Dr. J. J Lumpkin	do	do					500	791		800.00	1.60		45				
S. H. Lumpkin	do	do					525	791		600.00	1.00		45				
Henry King	Meridian	do						791									
James M. Robertson.	do	do						791									
S. J. Siddall	do	do						791									
Public Well	Iredell	do					345	881		$450.00	$1.30		28				
N. Bryant	do	do						881									
R. A. Rimer	do	do						881									
A. W. Childress	Kopperl	do					525	574									
M. and S. Logan	Morgan	do					800	734									
Muirhead Water Co.	do	dc					585	734		1,600.00	1.70		18				
Do	do	do						734		550.00			20				
R. P. Lowe	do	do					600	734					6				
J. L. White	do	do					580	734					18				
S. E. Moss	do	do					501	734					100				
Do	do	do					501	734					100				
James Holder	Kimball	do					600										
L. W. Chase	Cayote	do															
Koss Barry	Walnut Springs.	do						901									
W. M. Smith	Cranfill's Gap.	do															
S. V. Pool	Valley Mills	do						592									

TABLE No. 1.—*Location, elevation, depth, cost pressure, variation in flow*—Continued.

TEXAS—Continued.

Name of well.	Town or city.	County.	Location of well.			Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds.		Variation in flow per minute.		
			Section.	Township.	Range.									When flow is shut off.	When flowing.	Increase.	Decrease.	How much since first cased.
							Feet.		Feet.			In.						
Eulogy Well Co	Eulogy	Bosque					529			850.00	1.60		30					
A. G. Walker	do	do																
J. H. Osborn	do	do																
J. E. Brown	do	do																
Lee Scott Cattle	Tascosa	Dallam					230			450.00	1.95		15					
Syndicate Ranch		Hockley					75											
McCluskey	Yellow House Pasture.	Subbock					64											
Dave Taylor	Singer's Store.	do																
G. G. Gray	Midland	Midland					15			25.00	1.66		500					
Titus Machine Co	San Angelo	Tom Green					960											
W. S. Marshall (three wells).	Fort Worth	Hockley					120						5					
J. B. Gibson	Pecos City	Reeves					250			300.00	1.20	4	9					
W. S. Marshall	do	do					315			500.00	1.58	3	60		20			
Texas Pac. Rwy	do	do					220			440.00	2.00	4			12			
C. H. Merriman	do	do					185			351.00	1.89	3	60					
W. D. Johnson	do	do					185					3	60					
Do	do	do					185					6						
T. M. Clayton[1]	do	do					227					3						
Matherson & Walker.[1]	do	do					213					3						
Waltham & Powers.[1]	do	do					250					3						
P. Valley Land Co.[1]	do	do					237					3						
H. Phillips & Allen.[1]	do	do					237					3						
Denton Robertson.[1]	do	do										2						

A. T. Windom[1]	do	do										2					
W. D. Johnson & Co.[1]	do	do					235					3					
County Reeves[1]	do	do					227					3					
Chilton Bowen[1]	do	do										3					
C. H. Thalman	Bandera	Bandera															
A. M. Lauderdale	Bluff Dale	Erath					200						200				
William Dunning	do	do					350						200				
George Jackson	do	do															
Lauderdale and Greenwood. (Four Wells)	Pottsborough	Grayson					[1]250			[2]750.00			([3])				
Cool Jackson	Pal[illegible]xy	Hood															
Isaac Moore	do	do					150						50				
C. C. Meek	do	do					150						50				
John Meek	do	do					300						50				
W. S. Etheridge	do	do					236			250.00			50				
Coleman Carver	Whitney	Hill						586									
A. Jasper	Jacksborough	Jack					96	1,133		85.00			([4])				
Do	do	do					130			130.00			([4])				
R. G. Harrell	Gertrude	do															
W. R. Garvin	J. Thompson survey.	do								?							
L. P. Forbis	Virgil	Johnson															
American Carlsbad Water Co.	Cotulla	La Salle					1,003						([5])				
Coal prospectors	Waldrip	McCullough					110						([6])				
Bell Water Co.	Waco	McLennan					1,834			$7,200.00		8	([7])				
Do	do	do					1,834			5,000.00		5⅜	306				
Do	do	do					1,834					4¼	([8])				
Do	do	do					1,834					4¼	([8])				
Waco Water and Power Co.	do	do					1,812						([9])				
Do	McGregor	do											([10])				
Do	Lanham	Hamilton					470										
Do	do	do					500										
S. E. Morse	Eulogy	Bosque					780						50				
O. M. Acison	Brazos Point	do															
A. Wamble	do	do															
P. W. Williams	do	do															
L. S. Hine	Oakalla	Burnett															
Malloy Cattle Co.	Eden	Concho					987						7				
J. T. Webb	King	Coryell															
L. S. Sargeant	do	do															

[1] All these wells are bored within a circumference of 2 miles and all have continuous flow.
[2] Each.
[3] Flow estimated at 250,000 in twenty-four hours.
[4] Never fails.
[5] Several thousand per hour.
[6] Flowing salt water.
[7] 750,000 per diem.
[8] 300,000 per day.
[9] 1,200,000 per day.
[19] Strong flowing well.

Rider County: Several wells bored in this county. No accurate information obtainable.

TABLE NO. I.—*Location, elevation, depth, cost, pressure, variation in flow*—Continued.

TEXAS—Continued.

Name of well.	Town or city.	County.	Location of well. Section.	Township.	Range.	Date of completion.	Total depth of well.	Number of feet above sea level.	Elevation above nearest railroad station.	Total cost.	Price per foot.	Diameter of bore.	Flow in gallons per minute.	Pressure in pounds. When flow is shut off.	When flowing.	Variation in flow per minute. Increase.	Decrease.	How much since first cased.
							Feet.		*Feet.*			*In.*						
James Gidson	King	Corvell																
James Bashom	do	do																
J. F. Bashom	Pidcock R'ch	do																
Eli Williamson	do	do																
W. L. Bridges	do	do																
H. S. Perryman	do	do											5					
W. Carlisle	Gatesville	do											5					
J. J. Brick	Dallas	Dallas					700			$1,800.00			12					
City Park well	do	do					672						15					
On M. C. Hill's place.	Arlington	do					120						(1)					
T. J. Mumane's place.	do	do					15						(2)					
A. Rust's place	do	do					15						(3)					
Judge J. D. Terry	Cuero	De Witt						177										
S. S. Charles	Yorktown	do											8					
W. Eckhard	do	do					64			60.00			8					
Texas, Georgia, and Min. Sur., 1888.	Cisco	Eastland											(4)					
A. Rawlins	Eastland	do					400						(5)					
T. B. Applewhite	Pearsall	Frio																
C. H. Buve	do	do																
Texas Pacific R. R.	Toyah	Reeves					834					9	300					
Do	do	do					514					12	9					
Coal Co	Gordon	Palo Pinto					498	822		500.00	$1.00	1	1					
Do	Strawn	do																
Six or seven wells.	Springtown	Parker					100			100.00	1.00							
J. F. Johnson	Daltons	do																
O'Connor Bros	Refugio	Refugio					853						104					
Do	do	do					956						104					
Do	do	do					1,000						347					

Scott Milan	Walnut Springs.	Somervell					79			100.00	1.26		10				
O. M. Addison	do	do					387			500.00	1.45		10				
Do	Carrizo	Dimmit					175										
Geo. Abel	Glen Rose	Somervell					260			325.00			40				
Frank Maxwell	Wayland	Stephens					135										
S. C. Ellis	do	do					100										
Squire Hodges	do	do					120						6				
Satterthwaite	do	do					120						6				
J. F. Ford[3]	do	do					150										
J. S. Little[3]	do	do					150										
J. P. Rhea[3]	do	do															
J. T. Smith	Fort Worth	Tarrant					211	620					30				
A. J. Chambers	do	do					266						40				
W. F. Ross	do	do					300						30				
Frank Ellison	do	do					450										
L. W. Crawford	Fort Worth	Tarrant					465						30				
Fort Worth Ice Co.	do	do					360										
E. E. Daggett	do	do					300						70				
R. E. Maddox	do	do					320						30				
Town Council	do	do					930						140				
Texas Pacific Ry	do	do					450										
Do	do	do					760										
Fishing Club	Handley Station.	do															
H. S. Donoho	Utopia	Uvalde					200										
Do	do	do					102			$125.00		6	14				
Do	do	do					110										
Electric Light Co	Laredo	Webb					885										
Q. [illegible]	do	do					75										
C. Huerta	Cactus	do					170			450.00	$2.64						
Callaway	Taylor	Williamson					1,300										
Do	do	do					370						13				
Do	do	do					318						13				
J. K. P. Green	Rancho	Gonzales					[illegible]	2½		400.00	3.00		8				
Jas. M. York	do	do					192						3¾				
Jasper Boon	do	do					316						3				

[1] Small.
[2] 3 inch pipe flowing.
[3] Overflowing.
[4] Flowing salt water and gas.
[5] Flow of salt and mineral water.
[6] All are good flowing wells, costing from $50 to $200.

Somervell County: Wm. Lanham reports 100 to 150 flowing wells, ranging in depth from 120 to 320 feet. Dr. Scott Milan reports about 200 artesian wells within 12 miles of Glen Rose ranging in depth from 70 to 320 feet, in flow 2 to 300 gallons per minute, costing 75 cents per foot first 100 feet with 25 cents additional per foot for next 100 feet, etc. Robertson County: Large number flowing wells reported in this county. Tarrant County: Seven miles south of Fort Worth, strongest flowing well in county; nine wells on different surveys from 100 to 300 feet deep, all flowing. Calvert, Robertson County: Two flowing wells of small capacity in this town. Chrace Springs, [illegible] County: Dr. W. C. Frazier, R. W. Peters, John Pfeiffer, and W. C. Dickens own wells; no other information.

TABLE NO. II.—*Location, use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental.*

NORTH DAKOTA.

Name of well.	Town, city, or post-office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in non irrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				*Inches.*	*Inches.*				
Casselton City	Casselton	Cass	Town	Yes				No		$16\frac{1}{2}$	$16\frac{1}{2}$	No	$20	$100	$2.50
Roller Mill	do	do	do	Yes	Yes			No	40	$16\frac{1}{2}$		No	20	100	2.50
Devil's Lake	Devil's Lake	Ramsey	do	Yes						18		Yes	25		
Ellendale	Ellendale	Dickey	do	Yes				Yes				Yes	5	25	
Grafton	Grafton	Walsh	do	Yes											
Armstrong	Grandin	Cass	Stock	Yes				No		15		Partly	20	100	2.50
Weisbecker	do	do	do	Yes		Garden	Good								
Pratt	do	do	do	Yes		Grass	Good								
Hamilton City	Hamilton	Pembina	do	Yes						$19\frac{27}{100}$	$5\frac{68}{100}$	No	10	25	75
	Hillsboro	Trail	do	Yes				No		11		Partly	20	100	2.50
Searle	do	do	do	Yes											
Anderson	do	do	do	Yes											
Jamestown	Jamestown	Stutsman	do	Yes			Good	No				Yes	20	50	
Mayville	Mayville	Trail	Fire	Yes				No		11		Partly	20	100	2.50
Oakes	Oakes	Dickey	do	Yes											
Tower City	Tower	Cass	Town, etc	Yes				No		9	9	Partly	12	100	3.00
Stimmel	Wheatland	do	do	Yes	Yes		Good					Partly	25	50	50

SOUTH DAKOTA.

Name of well.	Town, city, or post-office.	County.	City, town, or farm.	Domestic.	For power.	Area irrigated.	Effect on crops, good or bad.	Can water be stored in non irrigating seasons?	How many acres can be served?	Mean annual rainfall.	In cropping seasons.	Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
Charles Stevens	Ashton	Spink		Yes	Yes		Good	No				Yes	15		100
J. W. Briggs	Beaver	Miner	Stock, etc	Yes		20	Good		30			No			
G. L. F. Johns	do	do	do	Yes	Yes			No				No	4		
Frederick	Frederick	Brown	Fire, gardens, etc.	Yes	Yes		Good	Yes				Yes	5		15
F. Alsagen	Gayville	Yankton	Stock	Yes	Yes										
E. Anderson	do	do	do	Yes	Yes										
J. L. Broatan	do	do	do	Yes	Yes										
N. H. Buckman	do	do	Dairy	Yes	Yes										

P. N. Crap	do	do	Stock	Yes				No			No				
J. Daugherty	do	do	do	Yes									20		
S. Douglas	do	do	do	Yes											
N. Dure	do	do	do	Yes							No				
W. Ericson	do	do	do	Yes											
S. C. Fargo	do	do	do	Yes											
S. Lane	do	do	do	Yes											
O. Lee	do	do	do	Yes				No							
M. Marfield	do	do	do	Yes											
M. McAlvane	do	do	do	Yes											
D. F. Money	do	do	do	Yes				No					20		
S. Olson	do	do	do	Yes									20		
C. Olson	do	do	do	Yes											
A. Peterson	do	do	do	Yes				No							
G. Peterson	do	do	do	Yes											
P. Peterson	do	do	do	Yes											
A. Stephenson	do	do	do	Yes									20		
M. M. Walker	do	do	do	Yes							No				
G. W. Young	do	do	do	Yes											
Asylum	do	do		Yes				No							
P. Johnson	do	do	Stock	Yes				No							
P. Larson	do	do	do	Yes				No				No			
S. Luck	do	do	do	Yes				No				No	20.00		
J. A. Pierson	do	do	do	Yes											
Press Brick Co.'s	do	do			Yes			No				No	20.00		
Stier & Ferdinand	do	do	Stock	Yes	Yes										
C. West	do	do	do	Yes				No							
W. P'land Cement Company.	do	do		Yes	Yes										
Yankton City	do	do	City	Yes								Yes	10.00	25.00	
P. R. Cruthers	Hetland	Kingsbury		Yes								No	10.00		
Fred G. Bolt	do	do	Farm									Yes	10.00	40.00	1.50
Kimball City	Kimball	Brulé	Town.	Yes								No	8.00	10.00	
Letcher Artesian	Letcher	Sanborn	Stock	Yes		20		No		22		Yes	5.00	10.00	
O. Adlamb	Meckling	Clay	Stock and dairy.	Yes											
G. W. Gilbert	do	do	do	Yes											
C. Miller	do	do	do	Yes											
O. Olson	do	do	do	Yes											
O. Olson, jr.	do	do	do	Yes											
M. Peterson	do	do	do	Yes											
Taylor's	do	do	do	Yes				No					15.00		
Mitchell City	Mitchell	Davison	City	Yes				Yes		28		No			
Edward Ericson	Roswell	Miner	Stock	Yes		100		Yes				Yes	10.00		
Scotland City	Scotland	Bon Homme	City	Yes				No				No	20.00	40.00	
A. J. Abbott	Tyndall	do	Stock	Yes				No				No	20.00	40.00	
Peter Byrnne	do	do	Irrigation	Yes		100	Good					Yes			
J. P. Cooley	do	do	Farm	Yes		5		No				Yes	20.00	40.00	
M. Jensen	do	do	Stock	Yes			Good					Yes	20.00	40.00	
L. Snyder	do	do	Farm	Yes		40		No					20.00	40.00	
Tyndall City	do	do	City	Yes		80		No				Yes	20.00	40.00	
A. Zeinart	do	do	Farm	Yes			Good	Yes				Yes	20.00	40.00	

TABLE NO. II.—*Location, use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental.*

SOUTH DAKOTA—Continued.

Name of well.	Town, city, or post office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in non irrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				*Inches.*	*Inches.*				
J. E. Delany	Vilas	Miner	Stock	Yes				No				Yes	$10.00		
Woonsocket City	Woonsocket	Sanborn	do	Yes				No		19		No	10.00	$30.00	
White Lake City	White Lake	Aurora	do	Yes			Good	Yes				Yes	5.00	100.00	$2.75

NEBRASKA.

Name of well.	Town, city, or post office.	County.	City, town, or farm.	Domestic.	For power.	Area irrigated.	Effect on crops, good or bad.	Can water be stored in non irrigating seasons?	How many acres can be served?	Mean annual rainfall.	In cropping seasons.	Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
C. W. Moss	Amelia	Holt	Stock	Yes				Yes				No	8.00		
T. S. Smith	do	do	do	Yes	Yes										
Caldwell & Sheets	Antelope	Antelope	do	Yes	Yes					$4\frac{9}{10}$		Yes	15.00	150.00	
Henry Bertz		Keith	do	Yes	Yes							Yes	6.00	30.00	4.00
Henry Moore		Deuel	do	Yes	Yes							Yes	6.00	40.00	
Wm. T. Jordan	Bliss	Holt	do	Yes	Yes	320						No	25.00		
Flowing	Chalmers	do	do									No	20.00	20.00	
P. L. Baker	Cornlea	Platte	Farm	Yes	Yes					32		No	40.00	80.00	
Moses Ham	Grand Island	Hall													
Wm. Jakob	Hayestown	Sherman	Stock	Yes				No					20.00		
Willie Calkins	Harold	Holt		Yes	Yes							No	8.00		
Lytle Bros	Herrick	Knox	Stock	Yes				No				No	15.00	30.00	
W. G Arnold's	Lamar	Chase	do	Yes				Yes				Yes	10.00	50.00	5.00
Hydraulic		Dawson	do	Yes								No	20.00		
Lisbon Town	Lisbon	Perkins	do	Yes						12		Yes	10.00	25.00	
C. W. Lemont	Minneola	Holt		Yes								Yes	6.00	25.00	.50
Geo. Shannon	do	do		Yes				Yes				Yes	5.00	30.00	1.00
C. D. Coles	Newport	Rock	Stock	Yes								No	8.00		
Water Works	Norfolk	Madison	City	Yes								No			
Union Pacific Railroad.	Omaha	Douglas		Yes	Yes										
D. L. and G. R. R.	do	do		Yes	Yes										
Fennick	Ogallala	Keith	Stock	Yes								Yes	10.00	30.00	
Santee Agency	Mission	Knox		Yes											

John Andres's	St. Helena	Cedar	Stock	Yes.	Yes.			Yes.				No.	12.00		
R. Wadsworth	Wayne	Wayne	do	Yes.	Yes.							No.	20.00		
A. H. Wright	Willow Springs	Garfield		Yes.	Yes.							No.	5.00		
Wallis	Sidney	Cheyenne	Stock	Yes.	Yes.					3		Yes.	25.00	500.00	1.50
							KANSAS.								
Bogue	Oberlin	Decatur		Yes.				Yes.		18	13	Yes.	$15.00	$250.00	$2.00
The Lexington	Lexington	Clark		Yes.				Yes.				Yes.	10.00	50.00	1.00
Strains	Jamestown	Cloud		Yes.				Yes.							
J. R. Morton	Protection	Comanche	Stock	Yes.						18½	6	No.	5.00		
The Bogue	Oberlin	Decatur		Yes.				Yes		20	14$\frac{85}{100}$	Yes.	5.00	25.00	
Artesian	do	do		Yes.				Yes.							
Nidigh	Cedar Bluff	do		Yes.				Yes.		26		Yes.		25.00	1.00
Artesian	Walker Station	Ellis	Stock	Yes.						2½		Yes.	10.00	25.00	
Philip Conboy	Hayes City	do	do	Yes.				Yes.				Yes.	5.00	50.00	
Do.	do	do								20	14				
Garden City	Garden City	Finney		Yes.						24	20	Yes.	3.00	500.00	3.00
E. C. Adams	Terrytown	do	Stock	Yes.	Yes.							Yes.	1.25	40.00	1.25
L. C. Hawes	Ford	Ford	do	Yes.								Yes.			
Frederick Mueller	Wilburn	do	do	Yes.						2		Yes.	1.25	40.00	
Mueller's	do	do								19	14	Yes.	5.00	15.00	1.50
C. F. Hoadley	Loyal	Garfield										Yes.	5.00	20.00	
E. Hoyt	Fremont	Graham													
J. J. Rosson	Ulysses	Grant	Irrigation	Yes.	Yes.			No.				Yes.	5.00		
J. K. Sayre	Ensign	Gray								26		Yes.	5.00	30.00	1.00
John W. Hudson	Hess	do	Irrigation									Yes.	2.00	65.00	1.00
Wm. McGlashen	Horace	Greeley	do	Yes.	Yes.							Yes.		20.00	2.00
J. White's	Macomb	Gray	do	Yes.						15		Yes.	5.00	50.00	2.00
Eugene Tilleux	Tribune	Greeley						Yes.		12½	9	Yes.	5.00	50.00	1.00
Peck's Opera House	Coolidge	Hamilton	(Medicinal)		Yes.						3	Yes.	5.00	15.00	
Peck Water Works	do	do	City	Yes.	Yes.							Yes.			
T. B. Nolan	do	do	Stock	Yes.				Yes.				Yes.			
J. H. Borders	do	do		Yes.								Yes		100.00	
A. W. Koerner	Syracuse	do	Irrigation	Yes.				Yes.		3		Yes.	4.00	12.00	1.25
Newton, M. & I. Co.	Newton	Kearney											50.00	60.00	
Do	Sec. 16, T. 21, R. 1 E.	Harvey										No.	30.00		
Santa Fé	Lockport	Haskell										Yes.	5.00	25.00	
Do.	Lakin	Kearney				200		Yes.					5.00	20.00	1.00
Andon Eliason	Spring Lake	Meade		Yes		2		Yes.					.50	50.00	
A. J. Ochs	Jetmore	Hodgeman	Irrigation	Yes.								Yes	50.00		
Smoky Hill	Batavia	Ellis											6.00	12.00	
Do.	Weskan	Wallace											15.00	40.00	
C. M. Orr	Astor	Greeley	Farm	Yes.				Yes.				Yes.	3.00	40.00	
Bored	Chapman	Norton	do	Yes.							8				
Johnson City	Johnson	Stanton													
Geo. Tanner	Cawker City	Mitchell								26	19$\frac{6}{10}$	Yes.	25.00		
W. H. Noale	Walnut Grove	do		Yes.		12						Yes.	20.00	50.00	

TABLE NO. II.—*Location, use for town, domestic, and farm purposes; areas irregated, effects and needs of; land values and water rental*—Continued.

KANSAS—Continued.

Name of well.	Town, city, or post-office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				*Inches*	*Inches.*				
Cess	Cess	Morton									6		$5.00	$20.00	
Chantilly	Lakin	Kearney	Irrigation	Yes				Yes				Yes			$1.00
J. E. Carpenter	Morton	Morton					Good					Yes	5.00	50.00	
J. C. Kilbourn	do	do	Farm	Yes				Yes				Yes	125.00	165.00	5.00
Richfield No. 2	Richfield	do						Yes		11	5	Yes	6.00	30.00	1.00
Richfield No. 1	do	do	Irrigation	Yes		40	Good	Yes				Yes	6.00	30.00	1.00
Ross Calhoun	Ness City	Ness		Yes						23	12	No	10.00	50.00	
Utica	Utica	do													
Cunfman	Bazine	do	Farm	Yes						20		Yes	10.00	50.00	
Surprise	Norton	Norton	do	Yes				Yes		20	10	Yes	1.25	30.00	1.00
Henry Stahl	do	do	do	Yes								Yes	15.00		
John Austin	Clayton	do	do	Yes						20	12	No	5 00		
Farm	Pleasant Plains	Osborne	do	Yes						4½	1½	Yes	1.25	50.00	
Wm. Roadhouse	Osborne	do	Stock	Yes								Yes	15.00	100.00	
Sidney Viers	Alton	do	do	Yes	Yes			Yes				Yes	5.00	50.00	
Pleasant Coal Co.	Osborne	do											20.00		
W. F. Heberlin	Kill Creek	do								13	10	No	8.00	16.00	
Public	Osborne	do						Yes		9		Yes	10.00	40.00	
A. B. Tucker	Kearney	Kearney	Stock	Yes				Yes				Yes	10.00	30.00	
George Deusenbery	Mullinville	Kiowa	do	Yes								Yes			
Palmer	Humbolt	Lane	do	Yes	Yes			Yes				Yes		40.00	
P. Bertelsen	Harman	Lincoln	Farm	Yes	Yes					18	12	Yes	10.00	50.00	
Miller's	Winona	Logan	do	Yes	Yes			Yes		25			2.50	15.00	
Rodgers & Sniffen	Oakley	do	do	Yes	Yes			No		16		Yes	4.00	30.00	1.50
J. Milton	Seares	do	do	Yes	Yes					14	10	No	5.00	30.00	15.00
R. P. Cooper	Meade Center	Meade	Irrigation		Yes	10				6	3	Yes	5.00	50.00	2.00
Oliver Norman	Fowler City	do				10 to 20		Yes		6	3	Yes	2.00	25.00	
S. N. Zortman	do	do	Stock	Yes				Yes				Yes		30.00	
Cox's No. 1	do	do	Irrigation	Yes		10 to 15	Good	Yes		15		Yes	3.00	40.00	1.50
S. W. S. Co.	Meade	do	Sugar Mill		Yes			Yes				Yes	5.00	30.00	1.50
West Plains Public	West Plains	do		Yes	Yes			Yes		16		Yes	2.00	25.00	3.00

Joash	Joash	do	Stock	Yes	Yes										
Cox No. 2	Fowler	do	Irrigation	Yes		7 to 15	Good	Yes		20	15	Yes	3.00	30.00	1.50
Larned Mineral	Larned	Pawnee		Yes				Yes					15.00		
Wm. Zachariah	do	do						Yes				Yes	5.00	50.00	
H. C. Wey	Kirwin	Phillips						Yes				Yes	10.00	25.00	
Allen's	Logan	do	Stock	Yes								Yes	4.00	40.00	3.00
W. P. Binford	Caven	Pratt	do	Yes				No				Yes	10.00	30.00	
Republic Coal Co	Scandia	Republic								4		Yes	25.00		
Sterling Co	Sterling	Rice	Salt works		Yes					32	24	No	20.00	25.00	
Do	Hutchinson	Reno	Farm	Yes				Yes							
D. H. Budd's	Enfield	Rooks	do	Yes						13½			5.00		
J. V. Burroughs	Zurich	do	do							11	$6\frac{9}{16}$		20.00	50.00	
F. P. Hill	Stockton	do	do	Yes	Yes							Yes	5.00	10.00	
M. M. Minch	Pleasant Dale	Rush	do	Yes	Yes							Yes			
	La Crosse	do	Stock	Yes	Yes					5	3	No	15.00	40.00	
Schwabb	do	do	Farm	Yes	Yee			Yes				Yes	10.00	100.00	
Atchison, Topeka & Santa Fé R. R.	Rush Center	do	do									No			
D. A. Smith	Delhi	Russell	do	Yes				Yes				No	10.00		
Russell	Russell	do						Yes		6	5	Yes	15.00		15.00
W. C. Fore	Assaria	Saline	Farm					Yes		4		Yes	25.00	50.00	
A. N. & C. B. Case	Bavaria	do										No	25.00	75.00	
S. J. Carlson	Wonderly	do	Farm	Yes				Yes			5	Yes	15.00	35.00	5.00
Hall's	do	do	do	Yes				Yes				Yes			
Mapes	do	do	do	Yes						4		Yes	10.00	40.00	3.00
J. M. Helfrick	Pence	Scott	do	Yes	Yes							Yes	1.25	100.00	
Martin Heller	Wichita	Sedgwick										No	33.00	75.00	
Micheal Lill	Andale	do	Farm					Yes				No	25.00		
M. A. Low	Topeka	Seward	A., T. & S. F. R. R.	Yes	Yes										
Sugar Company	Liberal	do	Sugar w'ks	Yes	Yes							Yes	5.00	50.00	
T. J. McDermot	do	do										Yes	5.00		
Do	do	do	Farm	Yes						10	4	Yes	4.00	50.00	1.00
Chicago, Kansas & Nebraska R. R.		Sherman	Irrigation	Yes	Yes							Yes	4.00	25.00	
C. F. Mgill	Stafford	Stafford	Town	Yes	Yes		Good					No	11.00	25.00	
L. & C. R. R.	Seguin	Thomas	Railroad Co.	Yes	Yes					14	10	Yes	10.00	100.00	5.00
Railroad Co.'s	Brewster	do	Farm and Railroad Co.	Yes	Yes							Yes	10.00	25.00	
John Osley	Weskan	Wallace	Farm	Yes	Yes					11		Yes	5.00	25.00	2.50
Ed Carter	do	do	do	Yes				Yes							

COLORADO.

A. L. Ish															
Sterling	Sterling	Logan	Town	Yes								Yes	15.00– 30.00	50.00	.50
Do		Jefferson								17–18	11–13½	Yes	30.00–100.00	55.00–150.00	.50

TABLE NO. II.—*Location, use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental*—Continued.

COLORADO—Continued.

Name of well.	Town, city, or post office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				Inches.	Inches.				
John Brown	Sterling	Saguache	Town	Yes		40	Good	Yes	40–60			Yes	$25.00	$40.00	
Denver Tramway Company	Denver	Arapahoe													
Wm. A. Harnell	Georgetown	Clear Creek													
R. A. Southworth	Denver	Arapahoe	Irrigation	Yes											$0.25
J. B. Ish	Leadville	Lake													
Orchard	Littleton	Arapahoe	Irrigation	Yes			Good	Yes	15–18			Yes	100.00–200.00	150.00–200.00	1.50
Do	do	do	do	Yes			Good	Yes	15–18			Yes	100.00–200.00	150.00–200.00	1.50
C. Bucher		Costilla	do	[1]Yes			Good		400–600			Yes	10.00–25.00	25.00–50.00	1.00
Do	Zapato	do	Farm	Yes				No				Yes	20.00	30.00–40.00	2.00
Liberty Post Office	Liberty	Rio Grande	Irrigation	Yes		1	Good	Yes	(2)			Yes	5.00–10.00	15.00–20.00	1.25–1.50
Chritton, No. 1	Monte Vista	do	do	Yes			Good	(3)	20			Yes	2.00–10.00	10.00	1.00–1.50
Chritton, No. 2	do	do	do				Good	(3)	20			Yes	2.00–10.00	10.00	1.00–1.50
H. H. Marsh	Monte Vista (2 wells each.)	do		Yes				Yes		12	7	Yes	5.00–40.00	100.00	1.00
Streeter[4]		Boulder													
Davis & Day	Longmont	do	Stock	Yes								Yes	25.00	50.00	1.50
School Section	do	do	Irrigation	Yes		12	Good	(5)	20	16	4	Yes		50.00–100.00	2.50
Do	Hygiene	do										Yes		50.00–100.00	2.50
Do	Boulder	do		Yes								Yes		50.00	1.50
Cheyenne City	Cheyenne	Cheyenne													
Government	do	do								17		Yes	1.25–5.00	10.00–50.00	1.50
H. M. Kellogg	do	do	Stock	Yes									1.25	25.00	
Kenwood Park	Denver	Arapahoe													
Bloquin Julien		Prowers													
Albany Town	Albany	do	Town	Yes											
Wilde	Denver	Arapahoe	City	Yes											
Burlington Round House		Kit Carson		Yes											
W. H. Gentzler															
Larkspur	Larkspur	Douglas										Yes			

Reno Park	Denver	Arapahoe		Yes								Yes		100.00–500.00	1.00
Joseph Stanley															
Pub. School Dist. 9				Yes											
J. Cook, jr.															
State of Colorado															
E. Reithman															
Swan Anderson															
J. W. Epler															
Villa Park															
Wm. Shellabarger	Littleton	Arapahoe													
Mrs. B. Magnes	Sheridan		Irrigation	Yes											
J. L. Killie	Denver	Arapahoe													
Fred Miller	Ludlum	Yuma	Stock	Yes											
Artesian	Vilas	Baca													
A. C. Cauble	Wakeman	Phillips	Stock	Yes						15	8–10	Yes	$2.00– $3.00	$10.00–$25.00	$1.00
P. C. Breslin	Vilas	Baca	do	Yes				[6]	5		18	No	3.00– 10.00	20.00– 35.00	5.00
Artesian		Yuma	do	Yes								Yes	1.25	10.00– 15.00	
Do	Ludlum	do	do		Yes							Yes	4.00– 5.00		
Yuma Town Well	Yuma	do	Town	Yes	Yes							Yes			
Artesian	Holyoke	Phillips		Yes									5.00		
Do	La Junta	Otero		Yes						6			1.25	25.00	
Do	Lamar	Kiowa				½	Good	No		8 or 10	[7]	Yes		10.00–200.00	
Do	Water Valley	do										Yes	6.00	25.00	1.00
Deep Well of Sheridan Lake.	Sheridan Lake	do		[8]						10	2– 8	Yes	0	40.00	1.50
										4	3	Yes	2.00	10.00– 40.00	
Artesian	Seibert	Kit Carson													
Cheyenne	Cheyenne Wells.	Cheyenne	Town	Yes											
Artesian	do	do		Yes											
Erb	Thurman	Arapahoe		Yes								Yes	2.50	25.00	
Timber Culture	Alamosa	Conejos	Irrigation							6	3– 6	Yes	1.25	40.00	1.00–3.00
Charles S. Moore	Stanley	Costilla	Farm	Yes		5	Good	Yes	5			Yes	5.00– 10.00	15.00	.75
Artesian		Arapahoe	do	Yes		5	Good	Yes	10	1	[9]	Yes	10 00– 20.00	50.00	1.00
Del Norte	Del Norte	Rio Grande	Town	Yes				No				Yes		75.00	
M. Cline	Island Station	Arapahoe										Yes	10.00– 35.00	15.00– 50.00	1.50
C. N. Campbell	do	do													
George C. Griffin	do	do													
William S. Lee	do	do													
Artesian	do	do		Yes											
Do	do	do										Yes	25.00– 50.00		
I. A. McCool's	do	do		Yes					10			Yes			
A. R. McCool's	do	do		Yes								Yes	30.00–100.00	60.00–150.00	
John S. McCool	do	do	Farm	Yes				No				Yes	30.00– 75.00	100.00–125.00	
William Murray	do	do						No				Yes	30.00–100.00	60.00–150.00	
Fred Reithman	do	do													
D. E. Young	do	do													
St. Helier's Farm	do	do	Farm	Yes											
John Bell	Sheridan	do	do	Yes											

[1] Fish culture. [2] Sandy soil; water sinks; 2 acres might be irrigated. On heavy clay, 25. [3] Completed reservoir; stocking with fish. [4] Never tubed water is strong alkali; cattle do not like it; bitter; think it would be injurious to crops. [5] Reservoir has been built, which holds about 60 days' run. [6] Not without much cost. How's from July to October. [7] Nearly all. [8] Not used. [9] None; of no use.

TABLE No. II.—*Location; use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental*—Continued.

COLORADO—Continued.

Name of well.	Town, city, or post office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				Inches.	Inches.				
Rock Well	Lyman	Arapahoe		Yes.		8		(1)	(1)			Yes.	$30.00		$2.00
Sterling Town Well	Sterling	Logan	Town	Yes.							7		2.00– 5.00	$20.00– 35.00	1.00
Union Pacific R. R.	Stout	Larimer													
Loveland Artesian	Loveland	do													
Kit Carson	Kit Carson	Bent													
George R. Gooch	Minneapolis	Baca													
Montrose Nos. 1 and 2.	Montrose	Montrose	Town	Yes.						10	6	Yes.	10.00– 75.00		2.50
Government	Akron	Washington													
John Hess	Lamar	Prowers	Ranch	Yes.						$12\frac{58}{100}$	9	Yes.		40.00	1.50
Artesian		Arapahoe		Yes.				No.	5			Yes.			
Fort Logan	Fort Logan	do		Yes				(2)							
Charles E. Wyman	Petersburgh	do													
Mrs. M. Brantner and Jonas Brantner's heirs.	Island Station	do	Ranch	Yes.				Yes.	4	9	3	Yes.	50.00– 75.00		
Mrs. S. M. Black	Brighton	do	do	Yes.				Yes.	½			Yes.	100.00		1.50
Frank Aichelman	do	do		Yes.											
Andrew Hagus	do	do													
P. W. Snyder	do	do													
Scranton	do	do													
Taylor's Springs	Harrisburg	do		Yes.				Yes				Yes.	5.00– 8.00	25.00	
George C. Griffin'	Island Station.	do	Ranch	Yes.								Yes.		60.00	1.50
Mrs. D. A. Stewart	Brighton	do													
F. L. Moore	Derby	do													
Artesian	Denver	do											10.00		
E. L. Chatfield	Littleton	do	Ranch	Yes.				Yes.				Yes.	3.00– 20.00	100.00–500.00	1.50
J. S. Vanderlip	Island Station.	do													
H. A. Vanevery	do	do													
June F. Wolpert	do	do													
Mrs. R. Morris	do	do													
F. M. Morris	do	do													

Mrs. Sam'l Brantner	do	do													
F. C. Fowler	do	do													
F. D. Storm	Denver	do	City	Yes											
D. A. Montague	do	do	do	Yes				Yes	20			Yes	1,000.00		
Globe Smelter	do	do	do	Yes				Yes				Yes	1,000.00		
E. M. Loomis	do	do	do												
Artesian	do	do	do	Yes											
J. H. Webber	do	do	do	Yes											
John Brehruy	do	do	do	Yes											
Mr. H. Clark	do	do	do	Yes											
Conrad Burke	do	do	do	Yes											
Beaver Brook Water Company.	do	do	do	Yes											
J. Q. Charles	Denver	Arapahoe	City	Yes											
Mrs. S. M. Gleason	do	do	do	Yes											
Windsor Block	do	do	do	Yes											
Smith Bros	do	do	do	Yes								Yes	$50.00–$100.00		$2.00–$5.00
Jacob Jones	do	do	do	Yes											
Rouse Junction	do	do	do	Yes									2.00– 5.00	$15.00–$30.00	1.50
Artesian	do	do	do	Yes											
J. C. Hopkins	do	do	do	Yes									75.00	125.00	
J. G. Hopkins	do	do	do	Yes											
Wright & Pray															
C. R. Gallup															
Artesian	Island Station	Arapahoe		Yes								Yes	25.00	100.00	200.00
Do	Monte Vista	Rio Grande		Yes								Yes	10.00– 50.00	20.00– 75.00	1.00
Do	Alamosa	Conejos	Farm	Yes								Yes		10.00– 25.00	.25
W. G. Winbourn	Fort Lupton	Weld		Yes								Yes			1.00– 2.00
J. M. Munford's	Longmont	Boulder		(3)						12–14	6–7	Yes	0	50.00	2.00
Retreat Park	Denver	Arapahoe		Yes				(4)				Yes			1.50
Artesian	Brighton	do	Farm	Yes				Yes				Yes		10.00– 15.00	1.50
Do	Denver	do										Yes	25.00	50.00	.50
Do	Lamar	Kiowa													
Atchison, Topeka and Santa Fe.	Sedalia	Douglas													
Jones	do	do	Stock												
Peirce & Murray	Acequia	do	Irrigation	Yes		2	Good	(5)				Yes	20.00	40.00	1.50– 2.00
J. M. Fox	do	do	Stock	Yes											
Geo. Manhart	Sedalia	do	Irrigation	Yes											
J. W. Bowles															
Shuckhart	Littleton	Arapahoe		Yes								Yes	100.00	150.00	1.50
Fred Bemis	do	do	Irrigation	Yes		3	Good	Yes [6]				Yes			
W. W. Chapman	do	do	Stock	Yes											
Geo. J. Burnett	do	do	Irrigation	Yes		8		(7)	(8)						
David Linhart	do	do	Stock	Yes				Yes							
Schoolhouse	do	do													
Oscar Lehood	do	do													
Mrs. G. B. Elliott	do	do	Irrigation	Yes											
Frank Watson	Denver	do	City	Yes											

[1] Provided with 2 reservoirs; 2 acres can be served direct from well. [2] Tank storage is now used. [3] Medicinal purposes. [4] Not economically. [5] Some is heldin a water-tight cistrn. [6] Reservoir 25 by 30 feet, 2 feet deep; fills in about twelve hours. [7] Reservoir 150 feet square, 5 feet deep; can fill twice a week. [8] Forty in rows could flood ten.

TABLE NO. II.—*Location; use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental*—Continued.

COLORADO—Continued.

Name of well.	Town, city, or post office.	County.	Use of water: City, town, or farm.	Use of water: Domestic.	Use of water: For power.	Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall: Mean annual rainfall.	Rainfall: In cropping seasons.	Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
						Acres.				Inches.	Inches.				
Harrington's	Denver	Arapahoe	City	Yes				No	None			Yes	$10.00–75.00	$100.00–250.00	$1.00–3.00
W. W. Graves	do	do	do	Yes											
John Cline	do	do	do	Yes											
M. M. Phelps	do	do	do	Yes											
F. P. Watson	do	do	do	Yes											
American House	do	do	do	Yes											
Ph. Zang Brewing Co.	do	do	do	Yes											
John Wolff	do	do	do	Yes				Yes				Yes	200.00–350.00		1.00
Ph. Zang & Co.	do	do	do	Yes											
Louis Sanguinette	do	do	do	Yes											
Gov. Evans	do	do	do	Yes											
Electric Illuminating Co.	do	do	do	Yes				No							
Anheuser-Busch Brewing Co.	do	do	do	Yes	(1)										
M. D. Clifford	do	do	do	Yes											
Artesian	do	do	do	Yes											
Sand Creek House Well.	do	do	do	Yes											
D. A. Montague	do	do	do	Yes											
Mrs. E. M. Loomis	do	do	do	Yes											
A. S. Lamg	do	do	do	Yes											
Sand Creek House	do	do	do	Yes				Yes				Yes	50.00	100.00	2.00
S. Capitol Hill (artesian).	do	do	do	Yes											
Platte Land Co	do	do	do	Yes											
Bush & Morse	do	do	do	Yes				No	None	15		Yes			
E. Capitol Hill (artesian).	do	do	do	Yes						Slight		Yes	100.00–250.00		
McMurray Bros	do	do	do	Yes											
L. Dugal	do	do	do	Yes				(2)							

Independence	do	do	do	Yes.											
C. C. Towle	do	do	do	Yes.											
Do	do	do	do	Yes.											
Platte Land Co	do	do	do	Yes.											
Do	do	do	do	Yes.				Yes.						100.00–200.00	2.50
Mrs. C. H. Cook, No. 2.	do	do	do	Yes.											
David Walport	do	do	do	Yes.											
G. W. Sigler	do	do	do	Yes.											
G. Wooley	do	do	do	Yes											
J. C. Knowles	do	do	do	Yes.											
John J. Brewer	do	do	do	Yes.											
Mrs. C. H. Cook, No. 1.	do	do	do	Yes											
Platte Land Co	Denver	Arapahoe	City	Yes.											
Upper well on Cherry Hill Farm.	do	do	Farm	Yes.		2		Yes.	2			Yes.	200.00		
Lower well on Cherry Hill Farm.	do	do	do	Yes.											
J. O. Lawton	do	do	City	Yes.											
Artesian	do	do	do	Yes.	Yes.										
Bonita	do	do	Irrigation	Yes.		15	Good.	Yes.	30	14		Yes		150.00	
Levick			City												
J. Playter	Denver	Arapahoe	do	Yes.											
Dr. R. F. Price	do	do	do					(3)							
D. M. Richards	do	do	Irrigation.	Yes.		Several									
C. A. Olin	do	do	City	Yes.											
Military Post	do	do	do	Yes.											
Artesian	do	do	do	Yes.				(4)							(4)
A. C. Fisk	do	do						Yes.							1.50–$1.75
University Park	do	do		(6)						15		Yes.	(5)		1.50– 2.00
Artesian	do	do	Irrigation.	Yes.				No.					50.00–5,000.00	(8)	
Rosavale	Colfax	do	do	Yes			Good.	No.				Yes.			
Artesian	Denver	do	do	Yes.	Yes[7]				(9)			Yes.	25.00	200.00	2.00
Do	do	do	do	Yes.	Yes.							Yes.	10.00– 20.00	30.00–100.00	
Windsor Artesian	do	do	do	Yes.											
Artesian	do	do	Farm	Yes								Yes.			
Solomon Cline	do	do													
Littleton Heights	Littleton	do													
Frank Cayley	do	do													
Charles Moore															
John Curtis	do	do	Irrigation.	Yes.				No.							
H. H. Curtis, jr.	do	do		Yes.		2 to 3		Yes.							
H. H. Curtis, sr	do	do	Irrigation.	Yes.								Yes.			

[1] Steam and refrigerating machine.
[2] Use windmill, 150 barrel tank.
[3] Had a reservoir 200 by 200 feet.
[4] Only by artificial reservoirs. Our water for irrigating costs $2.50 per inch.
[5] Too small a flow for use. $50 to $100 for farm. Town lots $500 to $3,000. No value without water.
[6] Already irrigated.
[7] Making ice.
[8] At first about 100,000 gallons in twenty-four hours. Slight flow now; would not serve 1 acre.
[9] $15, best, most value from suburban locality.

TABLE NO. II.—*Location; use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values and water rental*—Continued.

COLORADO—Continued.

Name of well.	Town, city, or post office.	County.	Use of water. City, town, or farm.	Use of water. Domestic.	Use of water. For power.	Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall. Mean annual rainfall.	Rainfall. In cropping seasons.	Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
						Acres.				*Inches.*	*Inches.*				
Cutter, Brown, Horne & Carey.	Littleton	Arapahoe	Irrigation.	Yes.											
Peter Magnes	do	do		Yes.											
J. B. Mayers	do	do													
Hotel Well	do	do													
J. B. Mayers	do	do													
Do	do	do													
Do	do	do													
Do	do	do													
Peter Magnes	do	do		Yes.											
W. C. Sprague	do	do	Farm	Yes.											
Levi Palmer	do	do	do	Yes.											
Chas. E. Hill	do	do										Yes	(1)	(2)	
D. W. Hunter	do	do													
Orchard Grove	do	do		(3)											
R. I. Spottswood	do	do	Farm	Yes.		1	Good	Yes.	5			Yes.	$50.00–$300.00		$2.00
Wilde	Denver	do	City	Yes.				No.				Yes.	200.00		1.50
A. E. Meek	do	do	City irrigation.	Yes		(4)							50.00	$500.00	
Do	do	do	City	Yes.											
O. L. Bright	do	do	do	Yes.											
J. H. Moser	do	do	do	Yes.											
Greeley City Public Well.	Greeley	Weld	do	Yes						14	(5)	Yes.		40.00	2.00
Gov. B. H. Eaton	do	do	do	(6)											
Evans' Town	Evans	do	Town	Yes								Yes.	[6]20.00	35.00	1.50
Artesian	Greeley	do	City	Yes.			Bad								
Do	do	do	do	Yes								Yes.			
Florence Soda	Florence	Fremont		(6)				No.				Yes.	[8]33 1/3		1.50
Florence Oil and Refining Co.	do	do		(6)								Yes	[8]100.00		

Cañon City Oil Co. Well 1.	Stump	do		(6)				No				Yes	(7)		1.00–2.00
Thatcher	Hoehne	Las Animas		(8)				No		2	1	Yes		25.00	
J. R. Fariss	Pueblo	Pueblo		Yes				No							
Small's Timber Claim.	do	do	For trees			10	(9)		13			Yes	8.00– 10.00	40.00– 50.00	2.00
Columbia Heights	do	do						No				Yes			
Do	do	do		(6)				(10)							
Colorado Coal and Iron Co's.	do	do		Yes				No				Yes			
Mineral Park	do	do	Irrigation	Yes			Good	(10)		$10\frac{51}{100}$	$6\frac{22}{100}$	Yes		25.00– 50.00	1.50
Clark's Mineral Spring Co.	do	do		Yes			Good	(10)	15			Yes		50.00	1.50–2.00
Chas. Glynn	Henry	Conejos		Yes				(11)	10			Yes	1.00– 2.00	20.00–$30.00	1.00
Legion (8 wells)	La Jara	do	Irrigation	Yes				Yes				Yes		15.00– 40.00	.75
S. E. Newcomb's Ranch (17 wells).	do	do	Farm	Yes											
Alamosa Town	Alamosa	do		Yes					100	3		Yes	10.00–25.00		1.00
Ormand	La Jara	do	Irrigation	Yes		14		(12)	25–30			Yes	10.00–15.00	15.00– 25.00	1.00
Colorado Springs	Colorado Springs.	El Paso													

NEW MEXICO.

Petroleum Co	Fort Wingate	Bernalillo													
Santa Fé Co	Santa Fé	Santa Fé						Yes				Yes			
Dening Artesian	Dening	Grant								3		Yes		50.00	3.00
Development Co	Las Vegas	San Miguel										Yes		50.00	
Subscription	Raton	Colfax						Yes				Yes	3.00	18.00	
Artesian	do	do										Yes	3.00	30.00	2.00
Do	do	do													
Turner	Springer	do						Yes							

WYOMING.

Cheyenne City	Cheyenne	Laramie													

1 $150 to $300, in 40 to 160 acre lots.
2 Domestic and stock, and run in a pond stocked with fish.
3 Lake is 20 by 30 feet in diameter, 3 feet deep, fill in two days.
4 More than half the annual fall.
5 Not used.
6 Irrigated.
7 $25 to $300, under water. Land not watered but with drinking water accessible for stock, $5.
8 Water was to have been used by R. R. Co., but was not sufficient to be of any use.
9 Not suitable owing to strong soda character.
10 By an artificial reservoir.
11 Only in large ditches.
12 By an artificial reservoir.

TABLE NO. II.—*Location; use for town, domestic, and farm purposes; areas irrigated, effects and need of; land values aud water rental*—Continued.

TEXAS.

Name of well.	Town, city, or post office.	County.	Use of water.			Area irrigated.	Effect on crops, good or bad.	Can water be stored in nonirrigating seasons?	How many acres can be served?	Rainfall.		Is irrigation a necessity?	Value per acre of farm land.	Value under irrigation.	Annual rental of water.
			City, town, or farm.	Domestic.	For power.					Mean annual rainfall.	In cropping seasons.				
						Acres.				Inches.	Inches.				
S. O. Bulverde	Mecke	Bexar	Farm	Yes											
Do	Utopia	Uvalde													
Addison		Somervell	Irrigation	Yes		10		Yes				Yes			
Do	Glen Rose	do	Farm	Yes								No	$25.00	$50.00	
Three, Nos. 1, 2, and 3	Victoria	Victoria	do	Yes				Yes				No			$5.00
W. H. Belcher	Pidcoke Ranch	Coryell	Irrigation	Yes			Good	Yes		32		No	15.00	50.00	6.00
West End Artesian	San Antonio	Bexar	Farm	Yes				Yes							
M. E. Dlandt	Yorktown	De Witt				35		No		13		No	12.00	25.00	
City Water Works	Fort Worth	Tarrant													
Household	Paluxy	Hood	Farm	Yes		50	Good	Yes				No	15.00	50.00	
Ferinbrough	Wayland	Stephens	Irrigation	Yes			Good	Yes		1		No	4.00	20.00	
Center Point	Center Point	Jack								8		No	30.00	100.00	
Refrigerator and Canning Co.	Denton	Denton	Town	Yes	Yes			Yes				No	15.00		
Cotulla	Cotulla	La Salle	Irrigation	Yes						18	10	No	5.00	30.00	3.00
Kincaid	Oakalla	Burnet	Farm	Yes		375		Yes				Yes	25.00	50.00	4.00
C. Pettit	Fariner	Young													
W. Fambrough	Wayland	Stephens	Irrigation	Yes		40		Yes				No	5.00	20.00	
J. R. Lane's	Filis	Hill	do	Yes	Yes							Yes	25.00		
Center Point	Jacksborough	Jack	do	Yes	Yes			Yes				No	5.00	20.00	
A. E. Burge	Japonica	Kerr	do	Yes								Yes	20.00		
W. E. Rabb	Honey Creek	Llano										Yes	5.00	40.00	
Waldrip	Waldrip	McCulloch	Irrigation	Yes	Yes								5.00		
Moore's Artesian	Waco	McLennon	do	Yes	Yes			Yes				No	10.00	50.00	6.00
W. A. Fitch	Eagle Pass	Maverick								27	15	No	10.00	20.00	
Gordon Artesian	Gordon	Palo Pinto										Yes	10.00	20.00	
Water Works	Weatherford	Parker	City	Yes	Yes										
L. L. Shield	Trickham	Coleman								8		No	8.00		
L. McClesky	King	Coryell	Stock	Yes		1	Bad	Yes					12.00	100.00	
Davidson	Pecan Grove	do	Irrigation	Yes			Good	Yes		18	9	Yes	20.00	100.00	1.50
Gatesville	Gatesville	do	do	Yes	Yes	5		No		33	20	No	15.00		

Texas and Pacific R. R.	Denton	Denton	T. and P. R. R. Co.	Yes.	Yes.			Yes				No.	25.00		
Wm. Eckhard's	Yorktown	De Witt	Farm	Yes.									10.00	25.00	
S. D. Frazier	Carrizo Springs	Dimmit	Irrigation.	Yes		4 to 20	Good.	Yes.				No.	3.00	50.00	3.00
Luiderdale	Luiderdale	Erath						No.				No.			
Bluffdale	Bluffdale	do		Yes.	Yes.		Good.	Yes.				Yes.	10 00		
Jack Glen	do	do	Irrigation.	Yes.	Yes.			No.				No.	3.50	10.00	1.00
T. A. and J. W. De Vilbin.	Reep	Frio	do	Yes.	Yes.	3	Good.	No.				No.	2.00	20.00	1.00
Dr. J. K. P. Green	Rancho	Gonzales	do	Yes.	Yes.								15.00		
	Sherman	Grayson						Yes.				No.	10.00		
Edward L. Bridge	Navasota	Grimes		Yes.	Yes.			Yes.			8	No.			3.00
Archer City	Archer City	Archer						Yes.				Yes.	3.00	25.00	
McBluntzer	Pleasanton	Atascosa										Yes	5.00		
Crystal Ice Co	San Antonio	Bexar	Mfg. ice	Yes.	Yes.			No.							
C. Kampmann	do	do	(1)	Yes.	Yes.								12.00	50.00	
Banes	do	do										No.	10.00	100.00	
Pasture	Meridian	Bosque	Farm	Yes.	Yes.			Yes.				No.	5.00		
Meridian Art	do	do	do	Yes.	Yes.	5						No.	5.00	50.00	
Do.	do	do	do	Yes.	Yes.	3	Good.	Yes.				No.			
S. J. Lumpkin	do	do	do	Yes.	Yes.	6 to 10		Yes.		10	1	Yes.	5.00	50.00	
Iredell	Iredell	do	do	Yes.	Yes.	2		Yes.				No.	10.00	40.00	
A. W. Childress	Kopperl	do	do	Yes.	Yes.			Yes.					12.00		
Eulogy Co	Eulogy	do	do	Yes.	Yes.			Yes.				No.	12.00		
Water Co	Morgan	do	do	Yes.	Yes			Yes.		13	5	No.	12.00	300.00	
Meirend Co	do	do	Irrigation.	Yes.		100	Good.	No.		27	10	No.	15.00	500.00	
Coggin Bros	Brownwood	Brown													
Kincaid's	Oakalla	Burnet	Farm	Yes.	Yes.			Yes.	375			Yes.	20.00	60.00	5.00
Geo. Abel	Glen Rose	Somervell	Irrigation.	Yes.	Yes.	40	Good.	No.				Yes.	9.00		
Artesian	Wayland	Stephens		Yes.	Yes.	25		Yes				Yes.	5.00	20.00	
Artesian Ice Co	Fort Worth	Tarrant	Ice Mfg. Co	Yes.	Yes.										
Ice and Electric Co.	Calvert	Robertson	R. R. Co	Yes	Yes.							Yes.	20.00	50.00	
Railroad Co	Merkel	Taylor	do	Yes.	Yes.	25		Yes.		35	15	Yes.	15.00	150.00	
H. S. Donoho's	Ranch	Uvalde	Farm	Yes.				Yes.				No.	3.00	40.00	
G. Huerta	Cactus	Webb	do	Yes.				No.				No.	20.00	30.00	2.00
Hoggsett	Rhome	Wise	do	Yes.				Yes.					10.00	50.00	
Lee Scott Co	Tascosa	Oldham	do	Yes.						7		No.	5.00	35.00	
J. L. McDowell	Big Springs	Howard	Irrigation.	Yes.				Yes.				No.	4.00	50.00	5.00
Big Springs	do	do						Yes		15		Yes.			
Dave Taylor	Singer's Store	Subbock	Farm	Yes.						15	8	No.	3.00		
Houston and Texas Central Railroad.	Ochiltree	Ochiltree													
B. L. Croucher	Del Rio	Val Verde	Farm	Yes.	Yes.							Yes.	2.00	50.00	2.50
B. N. White	do	do	do	Yes.	Yes.										
Pecos Land Co	Dryden	Pecos	do	Yes.	Yes.					12		Yes.			
C. H. Merrisman	Pecos City	Reeves	Irrigation.	Yes.		12			20	5		Yes.	2.00	25.00	
J. W. Frickey	Cataline	Hemphill	Farm	Yes.	Yes.							No.	3.00	10.00	
L. W. Chase	Cayote	Bosque	do	Yes.								No.	10.00		

[1] Irrigation and stock.

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, Western Nebraska, Kansas, and Indian Territory; eastern Colorado and New Mexico; Texas, west of the ninety-seventh meridian.*

NORTH DAKOTA.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
	La Moure					200 flowing springs on James River.
	Trail					Have not suffered from drought.
	McHenry					
	Kidder	31	139	73		Several large ponds.
	....do	32	139	73		
	....do	12	140	73		
	....do	12	140	73		
	....do	14	140	73		
	....do	35	137	74		
	Pierce	13	153	73		Irrigated by springs, 160 acres.
	....do	18	154	73		
	....do	6	156	72		
	....do	8	157	71		
	....do	3	157	73		
	....do	35	158	73		
	Sargent	2	130	58		
	....do	27	132	56		
	Mercer	13	146	86		
	....do	16	144	86		
	....do	30	145	86		
	....do	20	144	85		
	....do	30	144	84		
	....do	30	145	84		
	Stark					Large number of small springs.
	Burleigh					
	Ransom	11	135	58		Three large lakes.
	....do	29	135	57		
	Dickey					Number of springs in west of county.
	Logan	3	133	71		
	....do	10	133	71		
	....do	8	133	71		
	Rolette					Of ponds, etc., 100.
	Cass					Several springs on Maple River.
	Ransom	26	136	58		At Fort Ransom Springs, 200 feet above river.
	....do	10	135	58		
	Pembina	16	159	56		A large number of ponds, etc.
	....do	16	160	56		
	Eddy		149	64		Important springs also.

NEBRASKA.

Name of spring or owner, when known.	County.	Sec.	T.	R.	Flow per day.	Remarks.
	Antelope	28	24	6 W.	4,320,000	Altitude between 1,750 and 1,900 feet above sea level.
	....do	27	25	8 W.	6,480,000	
Mineral Spring	....do	2	27	7 W.	4,320,000	
	....do	21	28	8	4,320,000	
	Banner	4	19	55 W.		All good, strong springs.
	....do		19	54 W.		
	....do		20	55		
	....do	21	20	55		
	....do	7	19	55		
	....do	14	18	56		Only few small springs.
	....do	7	17	53		
Williamsdale Ranch.	Boone					
Point of Rock Spring.	Box Butte	1	24	49		
Barrel Spring	....do	5	24	50		
Box Butte Spring	....do		27	47		
Britton Spring	....do		28	49		
	Brown	30	30	20		
"Seven Springs"	....do	1	29	20	19,200	Large number of springs here.

TABLE III.—*Natural springs, reported by the artesian wells investigation, in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

NEBRASKA—Continued.

Name of spring or owner, when known.	County.	Location.			Flow per day.	Remarks.
		Sec.	T.	R.		
					Gallons.	
	Brown	...	...	...	...	At Long Pine, several fine springs.
	Cedar	34	32	1 W.	...	
	Chase	16	8	36	...	
	Cheyenne	...	20	51	...	
	....do	18	17	52	...	
	Clay	2, 3	8	7	...	A number of springs.
	Custer	1	15	23	...	
	...do	33	15	23	...	
	...do	2	15	23	...	
	....do	10, 3	16	24	...	
	...do	29	16	23	...	
	....do	13	16	24	...	
	...do	23	15	22	...	
	...do	7	14	21	...	
	....do	23	14	20	...	
	....do	23	16	26	...	
	....do	25	16	26	...	
	....do	1	16	26	...	
	....do	25	17	25	...	
	....do	...	16	26	...	
	....do	22	19	21	...	
	....do	...	18	17	...	
	....do	26	20	23	...	
	Dawes	29	33	46 W.	...	
	....do	...	32	49 W.	...	
	....do	...	33	44 W.	...	
	Deuel	...	...	...	...	
Lost Creek heading.	...do	27	18	44	...	Creek supplied by springs.
	....do	14	19	44	...	
	....do	32	19	43	...	
	....do	9	18	43	...	
U. P. R. R. tanks	....do	25	13	42	...	
	....do	20	14	41	2,700	
	Franklin	32	2	15	...	Well supplied with springs.
John Manning	Furnas	27	4 N.	25 W.	...	Very fine spring.
	...do	1, 2	5 N.	22	...	Very fine spring with strong flow.
	....do	36	4	23	...	
	....do	31	2	24	...	
	....do	29	1	25	...	
	Keith	8	12	40	...	A spring of water of fine quality, supplies 40 families; above Platte 150 feet.
	....do	3	12	40	...	
	....do	2	12	40	...	
	....do	4	12	40	...	
	Loup	30	22	20	...	
	Madison	22	22	2 W.	...	
	....do	35	23	5 W.	...	
	Nuckolls	9	3	5 W	...	
	....do	22	2	8 W.	...	
	....do	14	2	5 W.	...	
	....do	21	3	7 W.	...	
	....do	16	1	6 W.	...	
	....do	23	1	8	...	
	....do	19	1	8	...	
	Perkins	14	10	36	...	
Frenchman River	Chase	6	43	...	...	
	Phelps	28	5	20	...	Spring Creek fed by springs.
	....do	26	5	20	...	
	....do	5	5	20	...	
		25	5	21	...	
	Rock	NE. 30	30	17	...	
	....do	NW. 29	30	17	...	
	....do	SE. 29	30	17	...	
	....do	32	30	17	...	
	Scott's Bluff	4	20	55	...	
	....do	5	20	55	...	A great many strong springs rise in the "Hills," flow from 1 to 2 miles out of the valley, then sink under ground. Several springs.
	....do	6	20	55	...	
	....do	1, 2	20	56	...	
	....do	3	20	56	...	
	....do	28	21	56	...	

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

NEBRASKA—Continued.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
	Seward	2	9	1 E.		
	....do	17	9	2 E.		
	....do	20	9	2 E.		
	....do	18	9	1 E.		
	....do	25	10	3 E.		
	....do	21	10	4		Numerous springs.
	....do	12	9	3		
	....do	2	9	3		
	....do	29	9	4	4,466	Fine spring.
	Sheridan	22	30	43		
	....do	15	30	43		
	....do	23	30	43		
	....do	23	30	43		
Hay Springs	....do	8	31	46		Many springs in this vicinity.
Do	....do	35	32	47		
Do	....do	30	31	46		
Do	....do	28	31	46		
Do	....do	22	31	46		

KANSAS.

Name of spring or owner, when known.	County.	Sec.	T.	R.	Flow per day.	Remarks.
W. T. Rouse	Barber					There are many small springs in this county that feed small streams.
G. G. Shigley	....do					The country is full of small springs. They are found on nearly every creek.
J. T. Lewis	Barton	18	19	12		Strongly impregnated with salt.
Don. F. Lyman	Cheyenne					Thirteen miles above St. Francis; strong flow; many springs in vicinity; sheet water, 200 feet.
W. J. Workman	Clark					Many strong, never-failing springs are the origin of all the streams; water 50 to 300 feet below surface.
W. R. Daggett	....do					A few natural springs in Englewood.
Y. E. Beck	Comanche					There are numerous springs flowing to the surface in this county.
W. J. Cameron	....do					There is a good, large spring at Evansville; have heard of others.
J. B. Curry	....do	4	33	16		A huge old spring; under flow.
Do	....do	12	34	18		A good size spring.
I. N. Hall	Cowley					In Sheridan Township, in this county, there are many fine small springs.
Postmaster at Nescatunga.	Comanche	25	32	18		A strong flow.
Postmaster at Hope	Dickinson					Some small springs in the town.
Postmaster at Manchester.	....do	517	11	1		Very large spring; 40 feet from the head spring of Mud Creek.
Do	....do	5	11	1		The two strongest springs of Badger Creek in Clay County.
Robert McMillen, sr	....do	5	13	4		Sufficient power (if properly utilized) to run a mill.
I. L. Peck	Decatur	12	5	29		
H. H. Trazen	Cloud	35	7	2		
G. G. Mosher	....do	24	6	5		
M. C. Cline	....do	12	7	5		
Sherman Dotson	....do	2	7	4		
S. C. Wheeler	....do	17	5	4		
H. I. Hicks	Cowley	24	31	7		
J. B. Rowe	....do	1	32	7		
J. W. McClellan	....do	12	32	7		

TABLE III.—*Natural springs reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

KANSAS—Continued.

Name of spring or owner, when known.	County.	Location.			Flow per day.	Remarks.
		Sec.	T.	R.		
					Gallons.	
W. E. Miller	Decatur	21	5	29		Springs of good volume, indicating a good supply of subterranean water.
Parkes Drake	do	3	5	29		
Pohn McKennan	do	33	5	29		
Frank Kimball	do	32	1	30		
C. G. Bosworth	do	33	1	2		
Edward Kennedy	do	16	1	29		Springs are in water draws or near the banks of running streams.
Lewis Barr	do	31	1	29		
William Kennedy	do	15	1	29		
Frank Dimmick	do	10	1	29		
E. S. Sutton	do					Two miles northwest of Bossettville; quite a number of permanent springs are on the creek bottom.
J. R. Vancleare	do	20	4	30		Four strong springs; two fish ponds are supplied by one spring; soft water.
J. W. Mount	do	30	4	30		
Herbert Brooks	Rawlins	14	4	31		
E. T. Smith	Thomas	17	6	32		
S. M. Weston	Decatur	20	4	30		
J. R. Vancleare	do	19, 20	4	30		There are ten strong springs.
C. Schwaller	Ellis	26	12	16		A small spring; water scarce.
D. N. Beeston	Ellsworth	24	17	8		There are several other springs in this vicinity.
Ed. Skinner	do	26	17	8		
Robert Putnam	do	20	17	7		
H. B. Clark	do	16	17	8		
E. M. Waller	do	10	18	7		
D. H. Howard	do	33	15	7		These springs are never failing, and give a good supply of water; the most of them come out of side hills, and the water can be carried long distances; there are many springs in the county.
Theo. Sternberg	do	12	16	8		
Z. Jackson	do	27	16	8		
E. Becker	do	21	16	7		
G. R. Rathbone						
J. M. Jurel	Ford	33	27	22		
L. J. Gilson	Garfield					There are springs and pools too numerous to mention.
D. J. Hanna	Graham	24	9	21		
Jas. Noonish	do	16	7	21		
W. F. Hoyt	do	32	9	21		
E. E. Muelling	do	6	8	22		
J. M. Baker	Kingman	3	30	10		Large spring.
Do	do	3	30	10		
Stephen Carr	Barber	36	32	15		These springs have a large volume, each flows a stream 5 or 6 inches in diameter.
Jas. W. Dinsmore	do	11	32	15		
J. B. Ennis	Logan					A few springs in this county which might be used to irrigate.
B. H. Eearl	do	28	14	32		
N. W. Page	do		14	32		
Sam. W. Mercer	do	24	13	32		
P. W. Nudd	do					Used for irrigation.
J. C. Close	do	24	12	36		Water is found here at 70 feet to 140 feet on high land, and occasionally a spring on low land; good in quantity and of fair quality.
C. M. Davis	do	28	12	35		
E. M. Means	Meade					8 miles east of West Plains a large spring.
John Sims	do		30	26		Many other springs on Crooked Creek, which is supplied by springs.
Wm. Beatley	do		30	26		
R. E. Steele	do		32	28		Spring Creek has one of the largest springs in the State.
Andor Eliason	do	8	31	27		

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

KANSAS—Continued.

Name of spring or owner, when known.	County.	Location.			Flow per day.	Remarks.
		Sec.	T.	R.		
					Gallons.	
J. Werth	Meade	7	31	27		Intermitting spring.
H. L. McGinnis	...do	28	30	27		
H. C. Chose	...do	15	9	8		
Great Spirit's Spring Co.	Mitchell	15	9	8		The water is salt 200 feet down; below the salt water is fresh in sand rock.
Great Spirit	...do	25	6	10		Mineral.
J. Piper	...do	25	6	10		
Mary E. Anderson	Ness	28	16	22		A subterranean river.
B. W. Nolen	Garfield	14	22	28		Very strong.
H. C. Winter	...do	17	22	27		Subterranean, coming to the surface as a pool.
Seven Springs	Geary	19	12	5		
McGee	...do	19	12	5		
Big Spring	...do	33	11	5		
E. R. F. Morgan	...do	21	13	8		
C. B. Gill	...do	32	11	5		
W. E. Lonub	...do	23	12	8		
Wm. Bentley	...do	23	12	8		
Do	...do	30	12	8		
Chas. Murphy	...do	29	12	8		
John Cordry	Gove	19	15	29		
John Wolf	...do	22	13	30		
James Hamilton	...do	19	15	28		
J. M. Sears	...do	4	15	31		
G. C. R. Pierce	...do	12	14	28		
O. J. Wauzer	...do	32	10	26		
W. G. McIntire	Sheridan	2	10	28		
J. F. Matthews	Gove					There are numerous springs in the county.
G. G. Stumbs	...do	4	15	31		
Chas. O. Owen	...do	10	15	31		
H. C. Williams	...do	22	10	28		Very large spring.
John Keith	Graham	34	8	25		Abundance of water.
Charles Baker	...do	18	9	24		
Robert Richmond	...do	36	8	25		Fine spring.
Henry Palmer	...do	8	9	25		
Sam'l Mitchell	...do	23	8	23		
Kenyon	Hodgeman	10	21	25		
Yingling	Ness					There are some springs on the streams.
H. Stahl	Morton					Some springs along the creeks.
Newton Hill	...do					Our streams are fed by springs in counties west of us.
Robert A. King	...do					A few springs on north bank of Cimmaron River. This is dry part of time.
G. S. Vangundy	...do	27	33	41		Numerous springs.
J. C. Kilbourne	...do	17	33	41		Never dry.
J. W. Beatty	...do	12 6	33 33	42 41		A large spring. Have a buffalo park basin finely situated for irrigating, with ponds or lakes for holding supplies.
T. M. Walker	Osborne	16	9	22		Chain of fresh-water lakes.
W. M. Williams	...do					
William Rosepant	...do					
Henry Cooley	...do					
S. B. Farwell	...do	22	6	12		Plenty of water in the Solomon River. Few springs in the county.
S. E. White	...do	22	9	15		
Levi Guess	...do	22	9	12		
H. J. Brenner	...do	5	8	14		These three springs are probably from the same source, the first being near the head, the others nearer the mouth of a draw furnishing running water during the entire year in a wet season, and standing water constantly.
J. A. Fritsche	...do	3	8	14		
D. A. Snyder	...do	11	8	14		

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

KANSAS—Continued.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
J. A. Nelson	Pawnee	1	22	18		
Thomas Yeast	do	6	20	17		
T. J. Williamson	do	6	20	17		
J. C. Rundle	Phillips	13	5	20		Sufficient water for drinking and stock; not enough for irrigation.
William Lappen	do	13	5	20		
Thomas Dye	do	9	5	20		
William Graham	do	10	5	20		
H. J. Setchell	do	9, 10	4	20		
W. L. Porter	do					Springs abound along the small streams, which are numerous.
	Grant	29	27	28		
	do	33	27	38		
	do	5	28	39		
Heavy Spring	Grant	6	29	37		Second largest in county.
	do	18	29	36		
	do	17	29	36		
	do	35	29	36		
Wagon Bed	do	36	30	38		Strongest spring in county.
	do	12	29	38		
	do	34	29	36		
	Greeley	34	18	42		
	do	33	18	42		
	do		18	42		
	do		18	42		
	do	5	19	41		
Barrel Spring	do	35	17	42		
Wild Horse Corral	do	25	17	42		
Beaver Creek	do	2	16	39		There are several inexhaustible springs in this county which only rise to the surface.
	do		20	42		
	do	28	18	40		
	Hamilton	3	22	42		A great many springs here.
	Harper	11	32	5		
Crystal Springs	do	13	32	8		
	do	31	32	8		
	do	6	33	7		
	Harvey	29	22	2 E.		These springs are all small ones, but furnish a good supply of water.
Two Springs	do	32	22	2 E.		
Do	do	19	22	2 E.		
	do	3	22	2 E.		
	do	4	22	2 E.		
	Hodgeman	16	23	21		
Weak Spring	do	29	23	21		
Do	do	1	23	22		
	do	9	23	25		
	do	4	23	25		
	do	1	23	25		
	do	26	22	25		
	do	6	22	24		
	do		21	24		
	Kearney	17	24	35		
	do	10	24	34		
	do	20	24	35		
	do	16	24	35		
	do	17	24	35		
	do	13	25	37		
	Kingman	16	30	8 W.		There are fifty such springs in the immediate vicinity; all have pure, soft water, flowing stream from 3 in. to 1 ft. in diameter.
	do		30	10 W.		
	do		30	8 W.		
	do		30	7 W.		
	do		27	10 W.		
	do	32	29	10		
	do	3	30	10		
	do	4	30	10		
	do	2	30	10		
	do		30	8	5,760 to 720,000	There are innumerable springs in this vicinity. Flow varies as given.
	do	14	30	8		
	do	16	30	8		
	do		30	9		
	do		30	8		
Spring Creek	Kiowa		29	16		There are several large springs in this vicinity.
	do		29	16		
	do	12	30	18		
	do	25	30	18		About 100 springs in this vicinity forming creeks.

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

KANSAS—Continued.

Name of spring or owner, when known.	County.	Location.			Flow per day.	Remarks.
		Sec.	T.	R.	*Gallons.*	
	Kiowa	30	30	19		
	....do	16	30	20		
	....do	16	29	16		
	Lane	17	16	29		Fine spring.
Salt Creek	....do	16, 17	16	30		
	....do	17	16	29		Cheyenne River is headed by above springs; good volume of water. Plenty of water year round.
	....do	17	16	29		
	....do	19	16	29		
	....do	20	16	29		
	Lincoln	2	11	8		
	....do	26	10	8		
	....do	22	10	8		
	....do	14	10	8		
	....do	23	10	6		
	....do	23	10	6		
	....do	20	12	9		
Mineral Spring	....do	31	12	9		
Sub Creek	....do	10	12	10		
	....do	8	12	10		
	Meade		33	28 or 29		
	Rush	31	15 S.	15 W.		Strong, flowing spring.
	....do	25	15 S.	16 W.		Do.
	....do	2	16 S.	16 W.		A small spring.
	....do	33	15 S.	16 W.		Strong, flowing spring.
	....do	27	16 S.	16 W.		Abundance of water at surface.
	Russell	2	11	14 W.	1, 666	All soft water.
	....do	16	10	14	1, 666	
	....do	8	11	13	1, 666	
	....do	12	11	14	1, 666	
	....do	19	14	12 W.		
	....do	17	14	12 W.		
	....do	14	13	12 W.		
	....do	4	12	15		
	....do	18	11	16		
	....do	5	14	16		
	....do	18	13	15		
	Saline	2	15	2 W.		Heavy flow.
	....do	14	16	2 W.		Two springs, good flow.
	....do	2	1	2 W		
	....do	12	16	2 W.		Do.
	....do	34	16	2 W.		Good flow.
	....do	35	14	4 W.		
	....do	27	14	4 W.		
	....do	19	14	4		Strong flow soft water coming from sand rock; disappears after running a few rods.
	....do	6	14	4		
	....do	3	15	4		
	Scott	1	16	33		
	....do	12	16	33		
	....do	13	16	33		
	....do	24	16	33		
	....do	19	17	31		
	....do		16	31		
	....do		19	31		
	....do		18	31		
	....do		17	31		
Ingersoll Spring	....do	13	16	33		
	....do	NE. ¼ of NE. ¼ 36	27	2 E.		Spring 5 feet in diameter; gives water to run a mill.
	Sheridan	14	8	28		Several mineral springs here.
	Sherman	28	8	42 W.		
	Smith	19	2	13		Flowing.
	Stafford	8	22	11		
	Sheridan	12	8	31		
	Stanton	32	27	39		
	....do	30	27	39		
	Trego	12	13 S.	23 W.		
	....do	28	13 S.	23 W.		
	....do	11	13 S.	23 W.		
	....do	21	12 S.	22 W.		

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

KANSAS—Continued.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
	Trego	18	13 S.	24 W.		
	do	14	11	22		Strong, flowing spring.
		32	13	25		Do.
		22	13	21		Do.
	Trego	36	14	21		Very strong flowing spring.
	Meade	4	30 S.	26 W.		
	do	29	30 S.	26 W.		
	do	20	30	26		
	do	33	29	26		
	do	2	30	27		
Sharon Spring	Wallace	32	12	40		There are numerous springs in Wallace County, furnishing large quantities of water, which could be utilized for purposes of irrigation.
Farm Spring	do		12	41		
	do	20	14	39		
	do	11	11	39		
	do	30	13	39		
	do	17	14	39		
	do	4	15	38		
	Greeley	29	18	40		
	do	10	17	40		
	do	8	16	39		
Thomas Wilson	Phillips					There are numerous places where water oozing from the ground stands in pools.
D. G. Hoover	do					There are many springs, some flowing from bluffs far above the level.
William G. Mills	do					There are many springs; not sufficient for irrigation.
Thomas Dye	do					Many springs; not sufficient for irrigation.
E. I. King	do					Many springs about the creeks and rivers.
A. W. Crippen	do					Do.
M. Weed	do					Many springs where a few years ago there were no signs of water.
Frank Stockman	do	13	5	18		
J. T. Herring	do	12	5	18		
C. C. McManus	do	23	5	18		
Ephraim Kincaid	do	29, 30	5	17		These springs are never-failing. They form quite a large stream.
D. A. Duff	do	31	5	17		
J. Barnes	do					Plenty of never-failing springs in every township in this county.
E. Barney	do	27	3	16		Many springs; underground flow, 6 to 12 feet; an inexhaustible supply.
R. J. Stephenson	Rawlins	5, 8	3	34		Two very large springs; soft water.
J. B. Tobias	do					On my farm several springs come out of side hill 25 feet above bottom land.
David Seltzer	Reno	10	12	10		
J. B. Thatcher	do	10	26	10		
A. B. Graves	Republic	21	2	3		Two large springs good, soft water; others smaller on the sides of creeks.
C. Conkling	Rice					A few springs on the Little Arkansas.
Postmaster at Woodston.	Rooks					A few springs along Medicine Creek.
S. H. Baldwin	do					Many small springs in this vicinity.
Nat. Mullin	do					No important springs, but sheet water in abundance at 20 to 40 feet.

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

INDIAN TERRITORY.

Name of spring or owner, when known.	County.	Location.			Flow per day.	Remarks.
		Sec.	T.	R.		
					Gallons.	
	Public Land Strip.	18	2	24	....	
	....do	13	2	24	....	

COLORADO.

E. Bartel's.........	Cheyenne....	20	15	47	....	Constant flow.
Brush Cattle Co.'s.	Phillips.......	14	7 N.	46 W.	....	These springs have a small flow.
John Delay's	....do	14	6 N.	44 W.	....	
Peyton	Logan	29	7 N.	48 W.	....	
Palen Creek	....do	29	7 N.	48 W.	....	
Junis	....do	32	7 N.	50 W.	....	
	Kit Carson...	13	6 S.	46 W.	....	
Crystal	....do	7	8 S.	50 W.	....	
Buffalo	....do	31	7 S.	50 W.	72, 000	
Big Spring.........	....do	....	12 S.	49 W.	72, 000	
	....do	33	7 S.	50 W.	....	
Box................	Government land.	6	9 S.	48	....	
	Kit Carson ...	....	....	......	....	
Mulvane...........	Prowers	29	27 S.	47	21, 600 144, 000	
Butte (3)...........	....do	....	25 S.	42	....	
Willow	....do	4	25 S.	47 W.	....	
Tuttle	Arapahoe.....	13	6 S.	46 W.	....	
	....do	24	3 S.	45 W.	....	
Eureka	....do	3	4 S.	45 W.	....	
Shields	....do	25	3 S.	45 W.	....	
	....do	26, 27	3 S.	45 W.	....	
Bufalow	....do	34	4 S.	49 W.	....	
James F. Brezley ..	....do	34	4 S.	49 W.	....	Small flow.
Campbell	....do	26	10	69	28, 800	
Spring Cañon......	....	....	....	......	28, 800	
	Weld	....	11 N.	62	....	
Fleming	Pueblo........	32, 33	20	62	....	Large flow.
M. Sheldon's.......	....do	1, 6, 12, 24	18	65	....	
Iron	....do	22	22	67	....	Small flow.
Red Creek Spring .	....do	5	22	68	....	Do.
J. S. Edmondson ..	....do	31	24	67	....	Large flow.
Frank Pierson	....do	34	24	67	....	Do.
Haden & Dickenson	....do	24	24	67	....	Do.
State Spring	....do	36	24	68	....	Do.
Duckwartt	....do	21	24	66	....	Do.
Battle Ground.....	Logan	1	5	52	72, 000	
Nelson Powell.....	Kit Carson ...	33	7 S.	50 W.	....	
Beulah	Pueblo........	3	23	68	....	Nine springs on section.
Duck	Arapahoe....	22	5 S.	51	....	
Lusto & Duck.....	....do	8	6 S.	55 W.	....	
On Government land.	....do	1	3	54 W.	43, 200	
Buffalo	....do	34, 35	5	52 W.	43, 200	
	Washington ..	25	....	......	....	
Taylor's	Arapahoe.....	19	2 S.	53 W.	....	
Payton	Weld	13	7 N.	50	....	
Rock Spring.......	Washington ..	25	3 N.	53 W.	....	
Antelope	....do	9	1 N.	52	....	
Robinson	....do	14	2 N.	52	....	
Big Spring	Elbert	20	8	63	288, 000	
Geanbell...........	Arapahoe.....	7	4 S.	53 W.	....	
Tewin	Las Animas ..	2	30	50	....	
Mustang...........	....do	....	30	51	....	
Carizo Springs.....	Baca..........	....	....	......	....	
	....do	....	26 S.	43 W.	....	
Pony Cabler	....do	15	32	50	....	
	....do	33	28	48	....	A good volume of water all the year, feeding Butte Creek.
	....do	6	28	48	....	
	....do	32	28	48	....	
	....do	20	28	48	....	
Surface	....do	25	31	44	....	
	....do	20	32	43	....	
	....do	4	33	44	....	

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

COLORADO—Continued.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
	Cheyenne		14	47		Supply inexhaustible.
	....do		12	48		
Sheridan Lake	Kiowa					
Clark Spring	....do	30	19	53		
Sand Arroya	....do	6, 18	19	54		
Giller	....do	4	18	53		
Arlington Springs	....do	3, 10	20	53		
	Arapahoe	20	17	45		
	Kiowa	1	19	46		
	Kit Carson					
	....do					
	....do	15	8	49		
	....do	29	8	49		
	Logan	2	8 N.	52 W.		Many with good flow.
	Arapahoe		11 N.	52 W.		
	....do		11 N.	56 W.		
	....do	15	10 N.	59 W.		
	....do	34	11 N.	50 W.		
La Junta	Otero	3	24	55		
	....do	NE. ¼ 27	24	55		
	Prowers	NW. ¼ 4	25	45		
	Washington		5	52 W.		
	....do		5	51		
	Arapahoe	2	1 S.	43		
	....do	2	1 S.	44		
	Yuma	30	1 N.			Republican River is fed by springs.
	....do	1	1 N.	45		
	Furnas	13	1	25		
	....do	10	2	25		
	....do	3	2	25		
	Garfield	2	16	21		
	....do	10	21	16		
	....do		21	12		
	....do	34	22	18		
	....do	32	22	17		
Willow Springs	....do	33	21	15		
Do	....do	20	21	15		
Do	....do	13	21	16		
	....do	11	21	16		
	....do	10	21	16		
	Holt	22	26	13		A number of large flowing springs.
	....do	20	26	13		
	....do	13	26	13		
	....do	19	26	13		
	....do	15	26	13		
	....do	25	28	8		
	Kearney	6	6	13		
	....do	17	6	13		
	....do	2	6	13		
	....do	8	6	13		
	Keith	9	15	40		
	....do	34	13	38		
	....do	22	14	38		
	....do	12	12	40		

NEW MEXICO.

Name of spring or owner, when known.	County.	Sec.	T.	R.	Flow per day.	Remarks.
Lea Cattle Co.'s*	Lincoln	36	10 S.	23 E.	518, 400, 000	A great spring; forms a stream 50 feet wide.
North Spring*	....do		10 S.	24 E.		
South Spring*	....do		10 S.	25 E.		
Hudson Hot	Grant	20	20	11 E.	72, 000	
Chora					14, 400	
Memphis Mineral	Doña Aña				480, 000	
Chorro Jet						
Person		34	24	67		
		30	24	67		
		32	24	67		
		16	24	68		
Beckwith		27	24	67		
Heiklin		24	24	67		

* These springs form a large and permanent supply for the Rio Pecos. They immediately serve the canal system in that valley within New Mexico, by which 60,000 acres of land are already reclaimed. The service is equal to 300,000 acres.

TABLE III.—*Natural springs, reported by the artesian wells investigation in North Dakota, western Nebraska, Kansas, and Indian Territory, etc.*—Continued.

TEXAS.

Name of spring or owner, when known.	County.	Location. Sec.	T.	R.	Flow per day.	Remarks.
					Gallons.	
	Donley	83	Blk.C, 6			From 100 to 150 large springs
	....do	13	Blk.C, 6			
	....do	99	Blk.C, 6			
	....do	13	Blk.C, 3			
Houston and Texas Central Rwy. Co.	Lipscomb	264	Blk. 43			Strong, permanent spring.
	....do	343	Blk. 43			
	....do	90	Blk. 43			
	Midland					25 miles north of Midland.
	....do					18 miles south of Midland.
	Wheeler	58	Blk. A, 5			
	....do	40	Blk. A, 9			
	....do		Blk. A, 5			
	....do	6				J. Poitevent survey.
Texas and Pacific Rwy. Well.	Jeff Davis	56	Blk. 2			
	....do	8	Blk. 1			
	....do					A. S. Lewis survey.
	....do	22				
	Bandera					Survey No. 67.
	Bexar					2 miles north of San Antonio.
	....do					1 mile northwest of San Antonio.
Springs of Lampasas.	Lampasas					On Sulphur Fork.
	Cooke					A remarkable spring. The opening is 8 feet in diameter; water 1 foot from surface; supply not affected by droughts or rains. One mile from Rosston.
Ellison Springs	Eastland					Strong, permanent spring; 15 miles southeast of Eastland City.
McGough	....do					Strong, permanent spring; 4 miles south of Eastland City.
Wheat Springs						12 miles southwest of Eastland City.
Nash Spring	Eastland					12 miles south of Eastland City.
Sand Rough Spring.	....do					20 miles southwest of Eastland City.
Palo Pinto	....do					20 miles east of Eastland City.
Cotton Wood	....do					2 miles east of Eastland City.
	Hardeman					
	....do					
San Marcos	Hays					San Marcos.
Jacob's Well	....do					Large flow. Kyle.
Hanna Springs	Lampasas				240,000	Lampasas.
Hancock Springs	....do				240,000	Do.
Rishe Spring	Maverick					15 miles east of Eagle Pass.
Salado Spring	....do					22 miles southeast of Eagle Pass.
Rosita Spring	....do					7 miles southeast of Eagle Pass.
Soncito Spring	....do					7 miles northwest of Eagle Pass.
	Menard					
Coglan Spring, District No. 3.	....do					
Elm Spring	....do					

TABLE IV.—*Artesian wells in Utah.*

[Furnished by the local authorities.]

County.	Precinct.	No.	Depth.	Size of pipe.	Flow.	Acres irrigated.
			Feet.	*Inches.*	*Gallons.*	
Beaver	Star	4	285	$1\frac{1}{2}$	$4\frac{1}{2}$	None.
Box Elder	Willard	11	70–135	$\frac{1}{3}$, $1\frac{1}{2}$, $1\frac{1}{4}$	12–70	Thirty-four.
Cache	Logan	4	60	$1\frac{1}{2}$	15	None.
	Millville	9	30– 90	$1\frac{1}{4}$, $1\frac{1}{2}$	25–30	None.
	Mendon	3	60	$1\frac{1}{2}$	6	None.
	Newton	1	150	2	6	None.
	Petersboro [1]	12	200	$1\frac{1}{4}$	3	None; water consumed by stock.
	Wellsville	3	60	$1\frac{2}{3}$	15	None.
Garfield		1	100	$1\frac{1}{4}$	2	None.
Iron	Parowan	2	53–140	$1\frac{1}{2}$	3	None.
Juab	Whole county	16	85–190	$1\frac{1}{4}$–2	3–15	None; consumed by stock.
	Nephi	3	90–150	$1\frac{1}{4}$–2	15	None.
	Mona	13	85–190	$1\frac{1}{4}$–2	15	None.
Millard		40	165	$1\frac{1}{4}$	1–20	The whole county.
Pi Ute	Circleville	1	100	$1\frac{1}{4}$	2	None.
Sevier	Annabella	4	70	$1\frac{1}{4}$	5	None.
	Glenwood	2	64– 70	2	1–10	None.
	Vermillion	1	40	$1\frac{1}{4}$	2– 3	None.
Salt Lake	Granger	24	60–300	$1\frac{1}{4}$	4	Nono.
	Hunter	50	100	$1\frac{1}{4}$–2	....	
	Mill Creek	[2] 60	50–350	$1\frac{1}{2}$–6	....	None.
	North Point	24	100–300	$1\frac{1}{4}$	2	None.
San Pete	Chester	39	80–130	$1\frac{1}{4}$, $1\frac{1}{2}$, 2	6–40	None.
	Ephraim	[3] 100	100–140	....	20–30	None.
	Fayette	12	50	$1\frac{1}{4}$	5	None; used for domestic purposes.
	Gunnison	......	....	....	......	Tried without success.
	Manti	18	75	$1\frac{1}{4}$	35	One hundred.
	Mount Pleasant	1	60	$1\frac{1}{2}$	20	None.
	Spring City	3	28– 72	$1\frac{1}{2}$	25–35	None.
	Wales	3	75	$1\frac{1}{2}$	6	None.
Summit	....	......	....	....	....	
Tooele		[4] 201	50–250	$1\frac{1}{2}$	1– 80	Not estimated.
Utah	American Fork	15	100–200	$\frac{1}{2}$–4	25–250	About one hundred.
	Goshen	11	15– 16	$1\frac{1}{2}$	5	None.
	Lake Shore	58	40–300	$1\frac{1}{4}$	7	Ten.
	Lehi	300	75–260	$1\frac{1}{4}$, $1\frac{1}{2}$, 2	25	One hundred.
	Payson and Spring Lake.	6	80–200	$1\frac{1}{4}$	10	Three.
	Pleasant Grove	15	110–120	$1\frac{1}{2}$–3	40	One hundred.
	Provo	100	200	$1\frac{1}{2}$–2	30	One hundred; near lake shore, where not much water is needed.
	Salem	5	230	$1\frac{1}{2}$	5	None.
	Spanish Fork	141	[5] 150	$1\frac{1}{2}$	7	Two hundred.
	Springville	50	130–250	$1\frac{1}{4}$–4	5–400	Three hundred.
Wasatch	....	......	....	....	....	
Washington	....	......	....	....	....	
Weber	Eden	5	......	....	10	
	Harrisville	9	200	$1\frac{1}{4}$	20	Twenty-five.
	Hooperville	100	100–250	$1\frac{1}{2}$	....	Two hundred and forty.
	Lymore	3	140	2	35	Six.
	North Ogden	18	75–130	$1\frac{1}{4}$–2	3–50	Twenty.
	Plain City	[3] 200	100–200	$1\frac{1}{4}$–2	8–10	About five hundred.
	Slaterville	9	60–212	$1\frac{1}{4}$–$1\frac{1}{2}$	25	
	West Weber	[3] 100	100	$1\frac{1}{2}$	15	About one hundred and fifty.

[1] This precinct is not found in the Postal Guide or on map, but Petersburgh, in Millard County, is found in the atlas.
[2] Over. [3] About. [4] Whole county. [5] Average.

TOTAL NUMBER OF WELLS IN UTAH.

Beaver County	4	Salt Lake County	158
Box Elder County	11	San Pete County	176
Cache County	32	Sevier County	7
Garfield County	1	Tooele County	201
Iron County	2	Utah County	701
Juab County	16	Weber County	444
Millard County	40		
Pi Ute County	1	Total	1,794

Total number of acres irrigated, 1,993. "That is, about 1 acre to a well; each well costs (average) $30.50, or, say, $25 per acre at least."

TABLE V.—*Artesian and underflow town water works completed in the region between the ninety-seventh degree of longitude and the eastern foothills of the Rocky Mountains.*

NORTH DAKOTA.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
				Feet.	*Gallons.*	*Gallons.*	
Ellendale	Dickey	One artesian well	6 inches	1,087			
Oakes	....do	One artesian well (flowing)		853			
Devil's Lake	Ramsey	One artesian well		1,520	35,000		
Fort Totten	....do	Spring				48,000	
Jamestown	Stutsman	One artesian well (flowing)		1,500			
Grafton	Walsh	One artesian well		912		1,500,000	

SOUTH DAKOTA.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Plankington	Aurora	One artesian well (flowing)		545	[1]2		
Huron	Beadle	One artesian well (flowing)		863	1,500,000		
Scotland	Bon Homme	One artesian well					
Tyndall	....do	One artesian well	4½ inches	735			
Aberdeen	Brown	Two artesian wells (flowing)	6⅓ inches at top. 4½ inches at bottom.	906 1,000	3,000,000		Used for waterworks. Two other town wells being bored.
Columbia	....do	One artesian well (flowing)					
Andover	Day	One artesian well					
Mitchell	Davison	Two artesian wells (flowing)				1,000,000	
Faulkton	Faulk	One artesian well (flowing)		1,210			
Miller	Hand	One artesian well (flowing)	6 inches		3,900,000		
Highmore	Hyde	One artesian well (flowing)					
Spearfish	Lawrence	Spring			[2]209,455		
Salem	McCook	Well		225		50,000	
Rapid City	Pennington	Spring					Reservoir capacity 400,000 gallons.
Woonsocket	Sanborn	One artesian well	6 inches		[3]3,000		
Doland	Spink	Dug well	4½ feet	937.5	850,000		
Mellette	....do	One artesian well (flowing)					
Redfield	....do	One artesian well (flowing)					

NEBRASKA.

Hastings	Adams	Tubular wells				1,250 000	
Long Pine	Brown	Seven springs				250,000	
Kearney	Buffalo	Driven wells				3,000,000	
David City	Butler	Two Cook wells				1,000,000	
Broken Bow	Custer	Ten wells		[4] 100		1,000,000	Water in wells rises nearly to surface.
Aurora	Hamilton	Several wells				750,000	Wells pumped to reservoir.
Orleans	Harlan	Tubular well				24,000	
St. Paul	Howard	Thirty-two driven wells	2 inches			750,000	
Culbertson	Hitchcock	Tube-well				2,000,000	
Grand Island	Hall	Thirty-six driven wells	2 inches			2,000,000	
Fairbury	Jefferson	Wells				2,000,000	
North Platte	Lincoln	Driven wells		75 to 100		1,500,000	
Madison	Madison	...do		100			
Norfolk	...do	Two artesian wells		[4] 400		2,300,000	
Superior	Nuckolls	One dug well	25 feet	30		1,500,000	
Grant	Perkins	Wells				50,000	
Holdredge	Phelps	Two wells		[5] 200		2,500,000	
Stromsburgh	Polk	Cook wells				1,000,000	
Columbus	Platte	Sixteen driven wells	3 inches			2,000,000	
Seward	Seward	Cook wells					Standpipe capacity, 93,000 gallons; tank capacity, 50,000 gallons; 50 feet above town.
Rushville	Sheridan	Driven wells					
Loup City	Sherman	Four driven wells	3 inches			300,000	
Ord	Valley	Driven wells				750,000	
Red Cloud	Webster	Two surface wells				250,000	
York	York	Cook wells	6 inches			2,000,000	

COLORADO.

Highlands	Arapahoe	Artesian wells				1,500,000	Supplies part of North Denver.
Idaho Springs	Clear Creek	Mountain stream			1,450,000		By gravity.
Silver Cliff	Custer	Springs and surface water				1,000,000	
Colorado Springs	El Paso	Spring-fed stream (and mountain snow).				1,000,000	
Cañon City	Fremont	Ground water				2,000,000	
Black Hawk	Gilpin	Mountain springs			[6] 30,000		By gravity.
Berthoud	Larimer	Surface water					By gravity to 50-acre reservoir.
Central City	...do	Springs			[7] 26,400		By gravity to reservoir. Capacity, 525,000 gallons.
La Junta	Otero	Well	20 feet			950,000	
Fair Play	Park	Spring				(Unknown)	By gravity to and from reservoir.
Holyoke	Phillips	Well (probably)			[8] 64,000		By pumping to stand pipe.
Lamar	Prowers	Nine driven wells	Each $2\frac{1}{2}$ inches			500,000	To tank and direct.
Greeley	Weld	Well (and galleries)	14 feet	16 feet		1,000,000	To standpipe.

[1] Per minute. [2] Average daily flow. [3] Daily yield. [4] Each. [5] With 60 feet of water. [6] Daily. [7] Consumption. [8] Standpipe capacity.

TABLE V.—*Artesian and underflow town waterworks completed in the region between the ninety-seventh degree of longitude and the eastern foothills of the Rocky Mountains*—Continued.

WYOMING (EAST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
			Feet.	*Feet.*	*Gallons.*	*Gallons.*	
Sundance	Crook	Springs	...	...	[1]10,000	...	
Cheyenne	Laramie	Infiltration wells	...	...	[1]1,500,000	8,000,000	By gravity to and from reservoir; reservoir capacity, 60,000 gallons. Union Pacific Railway Company consumes 500,000 gallons.

MONTANA (EAST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Cascade	Cascade	Flowing artesian well	...	...	...	60,000	
Fort Keogh	Custer	Well	...	...	...	500,000	

NEW MEXICO (EAST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Clayton	Colfax	Springs	...	...	...	16,000	
Raton	do	Springs and well	...	...	...	230,000	

TEXAS.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Temple	Bell	Surface well	...	...	...	720,000	
San Antonio	Bexar	San Antonio springs	...	...	...	10,250,000	
Morgan	Bosque	Flowing artesian well	...	680	...	...	
Lockhart	Caldwell	Well	...	...	...	20,000	
Panhandle City	Carson	...	...	...	...	...	
Cleburne	Johnson	Pump, well, and springs	26 feet	26	...	1,250,000	
Colorado	Mitchell	Wells	...	...	...	350,000	
Weatherford	Parker	Large well with radiating tunnel	...	...	...	1,000,000	
Abilene	Taylor	...	...	...	...	750,000	
Fort Worth	Tarrant	Ninety-five gang well	2 inches	24	...	400,000	
Del Rio	Val Verde	Springs	...	...	...	...	
Taylor	Williamson	Springs	...	...	...	1,000,000	
Decatur	Wise	Well	...	...	...	72,000	

KANSAS.

Udall	Cawley	Well				150,000	
Bird City	Cheyenne	Four tube wells	3 inches	240		660,000	
Clay Centre	Clay	Surface water				2,000,000	
Clyde	Cloud	Steamed wells				150,000	
Concordia	...do	Cook well system				1,000,000	
Oberlin	Decatur	Thirty-two tube wells	3 inches	[2]35		1,000,000	
Abilene	Dickinson	Dug well	20 feet	40		1,250,000	
Kinsley	Edwards	Well				1,500,000	
Ellsworth	Ellsworth	Driven wells				1,200,000	
Garden City	Finney	Surface well				1,148,000	
Coolidge	Hamilton	Artesian well (flowing)	298½ feet			125,000	
Anthony	Harper	Eighteen driven wells				1,500,000	
Harper	...do	Artesian wells				750,000	
Greensburgh	Kiowa	Well	30 feet	96		150,000	
Marion	Marion	Well				2,000,000	
Peabody	...do	Five wells				500,000	
McPherson	McPherson	Two wells	145 feet each			275,000	
Windom	...do	Well				150,000	
Beloit	Mitchell	Well				1,750,000	
Norton	Norton	Eight Wagner wells		[2]23		500,000	
Downs	Osborne	Eight Wagner wells				500,000	
Minneapolis	Ottawa	Two dug wells, each 6 inches by 12 inches.		40 and 44			Daily yield, 100,000 gallons. Wells near Solomon River.
Larned	Pawnee	Dug well	30 feet	25		1,500,000	
Cullison	Pratt	Well				144,000	
Hutchinson	Reno	Driven wells (in conjunction with large dug well.)		[3]40 to 55		8,000,000	
Belleville	Republic	Wells				2,000,000	
Stirling	Rice	Thirty-eight driven wells	3 inches	[2]35		1,000,000	
Stockton	Rooks	Two dug wells	12 feet; 18 feet	9 and 34		500,000	
Bunker Hill	Russell	Springs				30,000	
Salina	Salina	One well		38		1,500,000	Fifty tubes, 75 feet deep, in bottom of well, to water gravel.
Wichita	Sedgwick	Ninety-six driven wells	Each 4 inches.	[2]35		5,000,000	
Conway Springs	Sumner	Well				1,000,000	
Greenleaf	Washington	Eight Wagner wells (steamed)	Each 6 inches	56 to 60			Yield more than 500,000 gallons daily.

[1] Consumption. [2] Each. [3] Driven wells.

TABLE VI.—*Showing the towns and cities west of the Rocky Mountain foothills, and within the arid region, that derive their water supply from underground and artesian waters.*

ARIZONA.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
				Feet.	*Gallons.*	*Gallons.*	
Tombstone	Cochise	Collecting reservoir fed in part by springs.				1,200,000	
Phœnix	Maricopa	Wells pumping to stand-pipe, tank, and direct.				3,000,000	

CALIFORNIA.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Alameda and Fitchburg.	Alameda	Four artesian wells				2,000,000	Water gathered in receiving well 30 feet deep and pumped to tank.
Haywards	do	Wells	25 feet	55		1,600,000	
Livermore	do	Livermore Springs				480,000	
Mission San Jose	do	Springs					Reservoir capacity 100,000 gallons.
Oakland	do	Artificial lakes and artesian wells					Lake Chabat, capacity 5,000,000 gallons; Seneschal Lake, capacity 270,000,000 gallons.
West Berkeley	do	Tunnels driven into hill and springs, by gravity.					Reservoir capacity 8,000,000 gallons.
Jackson	Amador	Springs and Blue Lake Company's Canal.					Reservoir capacity 3,000,000 gallons.
Chico	Butte	Surface wells				2,000,000	
Fresno	Fresno	Two wells	One 8 inches, one 10 inches.	[1] 100		3,500,000	
Selma	do	One artesian well		180		300,000	
Eureka	Humboldt	Combined surface and artesian wells.	Surface well 20 feet square, 47 feet deep; four artesian wells.	(2)		1,850,000	
Ferndale	do	Spring, by gravity					Reservoir capacity 300,000 gallons.
Bakersfield	Kern	Four artesian wells	Two 8 inches, two 10 inches.			1,000,000	
Centinela	Los Angeles	Inglewood Springs, developed by excavation, and artesian wells.				900,000	
Pasadena	do	Springs				792,000	
Pomona	do	Artesian well, by gravity			[3] 1,500,000		

Redondo Beach	do	Thirty-two artesian wells				1,500,000	Reservoir capacity 3,000,000 gallons.
San Gabriel	do	Flowing artesian wells and irrigating ditches.					
San Pedro	do	Wells				1,000,000	
Wilmington	do						
Merced	Merced	Artesian well		160		1,500,000	
Salinas	Monterey	Four artesian wells	10 inches each	(4)		1,000,000	
Napa City	Napa	Surface well	5 feet	47		720,000	Dam and reservoir, capacity 2,500,000 gallons.
St. Helena	do	Spring, by gravity					Reservoir, capacity 30,000,000 gallons.
Truckee	Nevada	Springs, by gravity					Tank, capacity 337,500 gallons.
Dutch Platt	Placer	do					Reservoir, capacity 180,000 gallons.
Hollister	San Benito	Three artesian wells	Each 10 inches	[1] 85		2,000,000	Reservoir, capacity 300,000 gallons.
Colton	San Bernardino	Old, five artesian wells; new, "Cienega."			(5)		
Cucamonga	do	Tunnels in volcanic hill and artesian wells; by gravity through reservoirs.					Five reservoirs, capacity from 2,000,000 to 3,000,000 gallons each.
Ontario	do	San Antonio Creek and infiltration tunnel beneath same; large part of water used for irrigation.					Consumption, about 3,000,000 gallons.
Riverside	do	Nine artesian wells	One 11 inches	117	[3] 345,000		
San Bernardino	do	Artesian wells					Reservoir, capacity 3,000,000 gallons.
Santa Barbara	Santa Barbara	Surface well	30 feet	36		1,000,000	
		Inside main well, two driven wells.	One 8 inches	160			
			One 2 inches	190			
Gilroy	Santa Clara	Two wells in dry weather	11 inches	100 to 120		2,400,000	
Escondido	San Diego	Three wells	20 feet	12		1,152,000	
San Diego	do	San Diego River and 14 wells	24 to 30 feet	15 to 25		6,500,000	Reservoir, 3,850,000 gallons.
Stockton	San Joaquin	Artesian wells; sixty small wells; twenty added in 1889.		(6)		4,500,000	
Nipomo	San Luis Obispo	Mountain springs					Reservoir, capacity 32,000 gallons.
Paso Robles	do	Springs				580,000	Reservoir, capacity 150,000 gallons.
Templeton	do	Well				300,000	
Redwood City	San Mateo	Salinas Water Works Company's system; supply at Salinas from artesian wells.				600,000	Three tanks, capacity 180,000 gallons.
Yreka	Siskiyou	Springs, by gravity				288,000	
Healdsburgh	Sonoma	Springs				500,000	
Modesto	Stanislaus	Two artesian wells	10 inches	[1] 116	1,200,000		
Oakdale	do	Well				250,000	

[1] Each.
[2] Artesian wells are 806, 293, 172, and 100 feet deep, respectively.
[3] Daily.
[4] 84, 87, 200, and 234 feet deep, respectively.
[5] Artesian wells yield of 15 miner's inches ($\frac{3}{10}$ cubic foot) per second. "Cienega" yields 34 miner's inches.
[6] Three wells are 975, 1,070, and 1,081 feet deep.

TABLE VI.—*Showing the towns and cities west of the Rocky Mountain foothills, and within the arid region, that derive their water supply from underground and artesian waters*—Continued.

CALIFORNIA—Continued.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
				Feet.	*Gallons.*	*Gallons.*	
Sonora	Tuolumne	Springs					
Tulare	Tulare	Two artesian wells		400			Reservoir, capacity 270,000 gallons.
		Two additional wells		500		2,304,000	
Visalia	do	Artesian wells					
Woodland	Tolo	Four artesian wells				840,000	
Wheatland	Yuba	Well		200		1,000,000	
						288,000	

COLORADO (WEST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Silverton	San Juan	Springs			(1)		By gravity, from reservoir.

NEVADA.

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Candelaria	Esmeralda	Springs (from 300 feet to 1,000 feet head).					By gravity; reservoir. capacity 500,000 gallons.
Eureka	Eureka	Springs (to tanks)					By gravity; tanks (6), capacity 250,000 gallons.
Pioche	Lincoln	Two springs (to tanks), 300 feet head.			2 30,000		By gravity to two tanks; capacity 200,000 gallons.

NEW MEXICO (WEST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
Albuquerque	Bernalillo	One surface well	20 feet	25		3,000,000	
		Fifty-two driven wells	3 inches	40			
Silver City	Grant	Wells		60		1,000,000	
Socorro	Socorro	Mountain springs				200,000	

OREGON (EAST OF CASCADE RANGE).

Baker City	Baker	Six artesian wells	3 and 4 inches	75 to 155	(3)	750, 000	
Pendleton	Umatilla	Well				1, 000, 000	
Weston	do	Spring-fed stream			480, 000 [4]		By gravity; reservoir, capacity 100,000 gallons.
Hood River	Wasco	Spring (150 feet head)					By gravity; spring 150 feet above town.

UTAH.

Nephi	Juab	Springs, by gravity, 160 feet above city.					Reservoir, capacity 30,000 gallons.
Salt Lake City	Salt Lake	Spring-fed stream			[2] 10, 000, 000		By gravity to reservoir; several artesian wells reported.

IDAHO.

Ketchum	Alturas	Springs, by gravity					Reservoir, capacity 100,000 gallons.
Boisé City	Ada	Ditches, fed by springs					
Pocatello	Bingham	Mountain springs and river, by gravity and pumping.				350, 000	
Moscow	Latah	Driven wells, pumping direct					Bonds voted and contract let; estimated price $25,000.

MONTANA (WEST OF FOOTHILLS).

Bozeman	Gallatin	Spring-fed mountain stream				1, 250, 000	
Helena	Lewis and Clarke	One surface well Twelve driven wells	$4\frac{1}{2}$ feet 4 to 6 inches	$26\frac{1}{2}$		2, 800, 000	

WASHINGTON (EAST OF CASCADE MOUNTAINS).

Roslyn	Kittitas	Mountain stream, by gravity					Consumption 2,000 gallons.
Sprague	Lincoln	Well, pumping				720, 000	
Walla Walla	Walla Walla	Springs, by gravity					Two reservoirs; capacity 1,900,000 gallons.
Pullman	Whitman	Seven flowing artesian wells		78 to 100	(5)		From one of these wells city will be supplied.

Reservoir capacity, 1,000,000 gallons. [2] Daily. [3] Syphon in one well gives 6,000 gallons per hour. [4] Consumption. [5] Three flowed upwards of 1,000 gallons per minute.

TABLE VI.—*Showing the towns and cities west of the Rocky Mountains and foothills, and within the arid region, that derive their water supply from underground and artesian wells*—Continued.

WYOMING (WEST OF FOOTHILLS).

Town.	County.	Source of supply.	Diameter of well.	Depth of well.	Flow.	Pumping machinery, daily capacity.	Remarks.
				Feet.	*Gallons.*	*Gallons.*	
Laramie City	Albany	Springs					Used for fire protection in city
Dana (and Hana)	Carbon	Mountain springs	8-inch casing	525			
Rawlins	do	Artesian well				150,000	

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DEPARTMENT OF AGRICULTURE
According to Act of Congress April 4th 1890
showing the location of
Artesian Wells and Waters
July 1890.

RICHARD J. HINTON Special Agent in Charge.
Edwin S. Nettleton, Supervising Engineer.
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Division I
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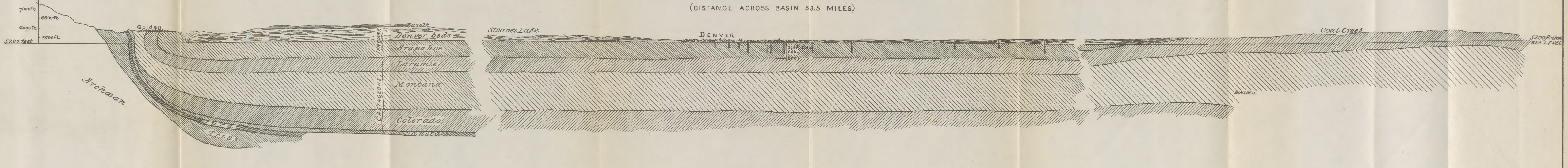

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